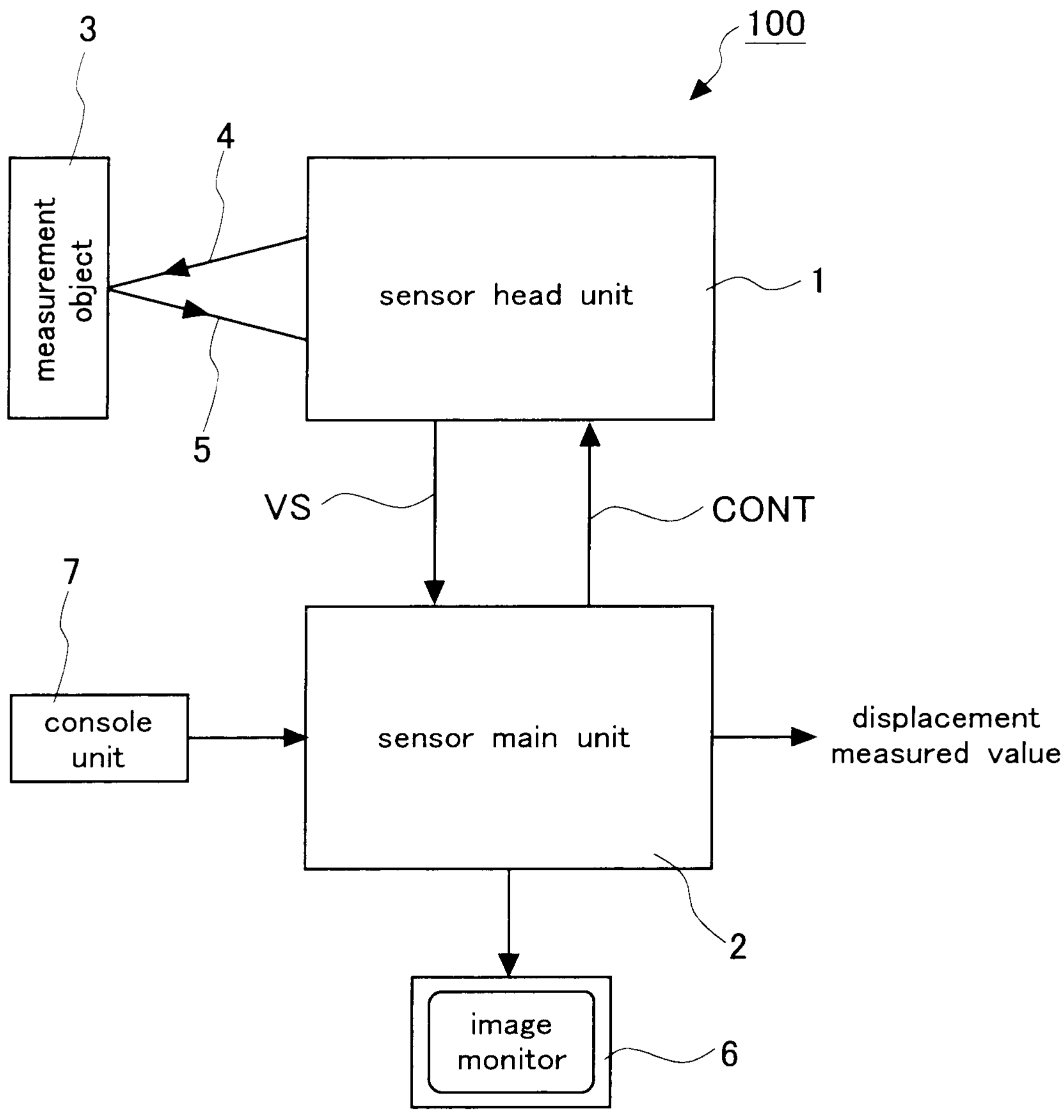
Fig. 1

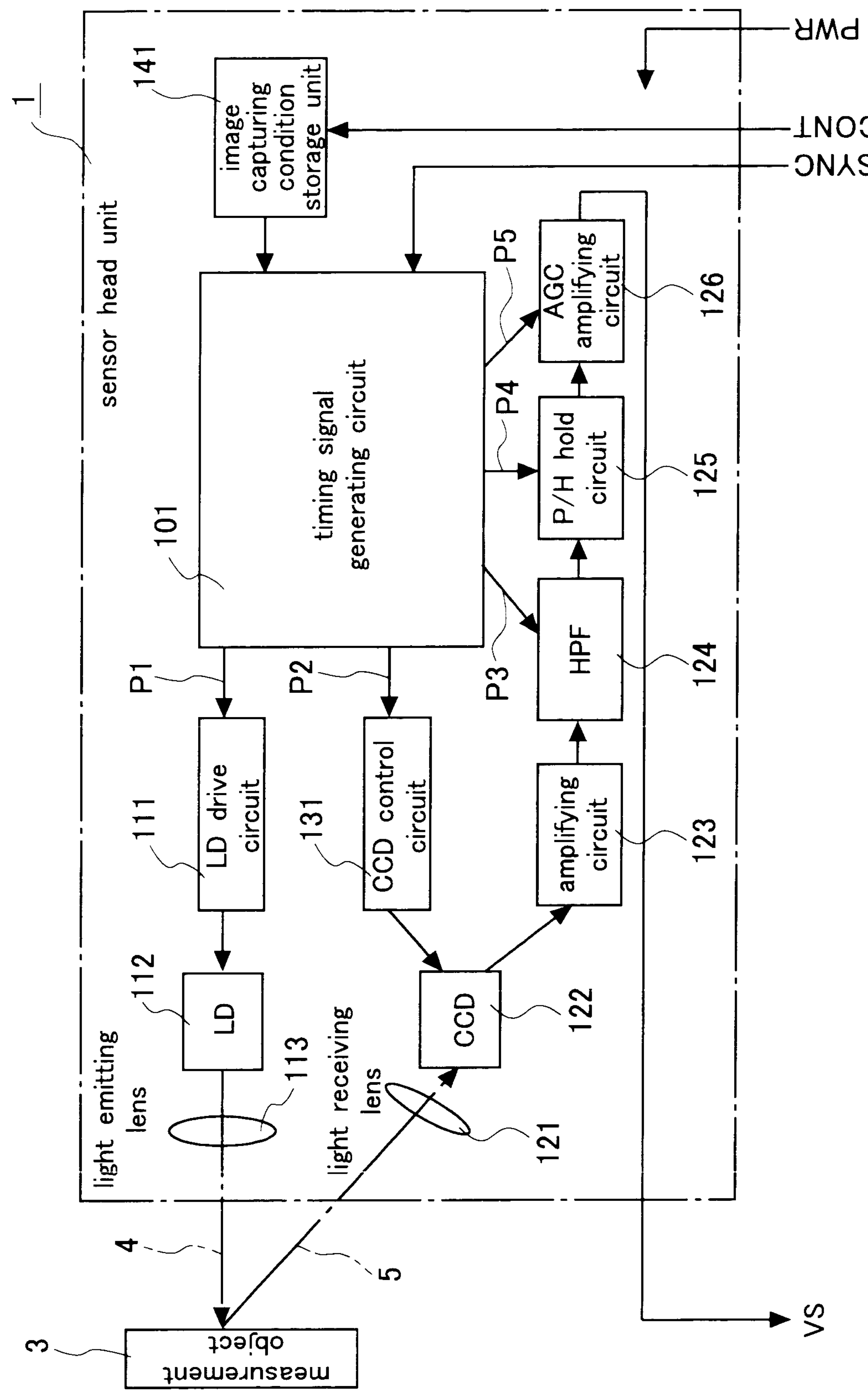


An overall view of a visual displacement sensor

09/937480

Title: VISUAL DISPLACEMEN
SENSOR
Inventor(s): Tatsuya Matsunaga, et al.
DOCKET NO.: 058856-0106

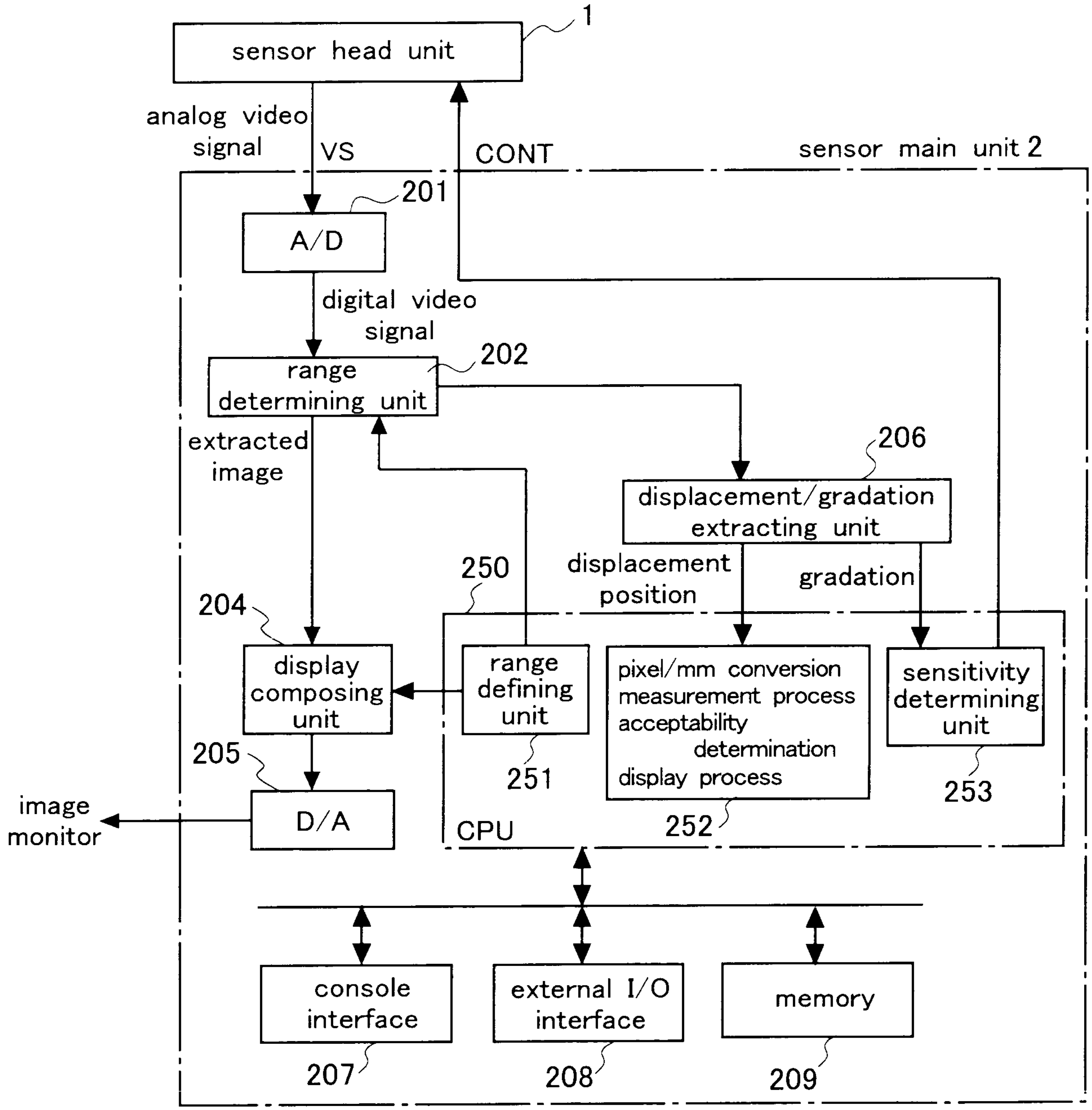
Fig. 2



A view showing the internal structure of the sensor head unit

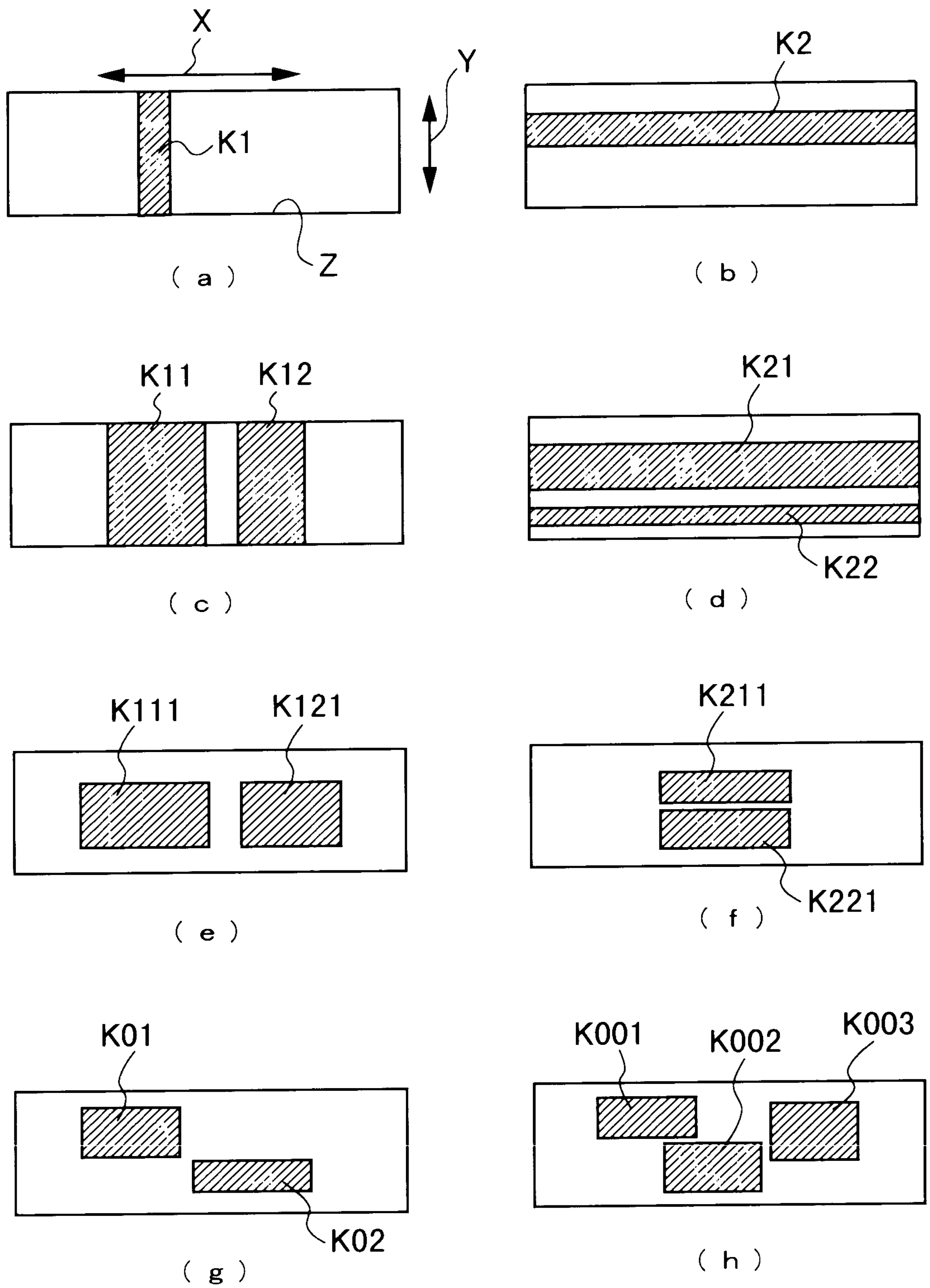
09/937480

Fig. 3



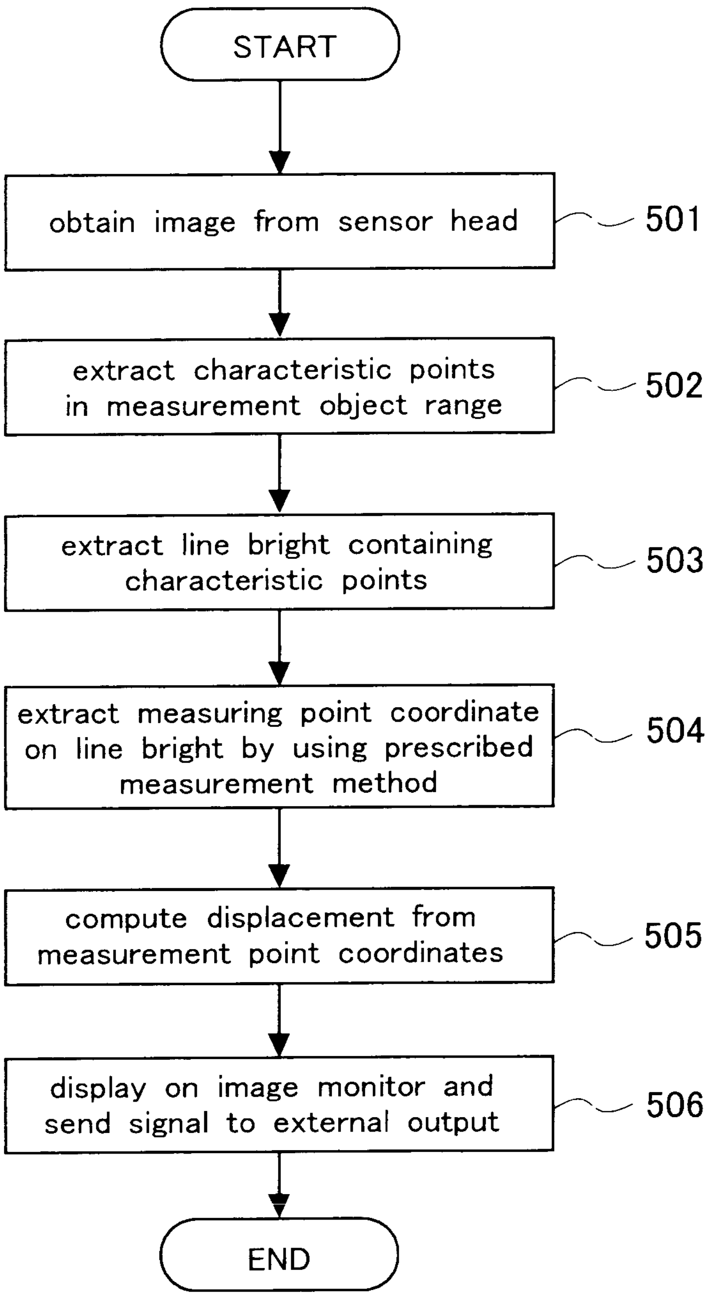
A block diagram (part 1)
showing the functional internal structure of the sensor main unit

Fig. 4



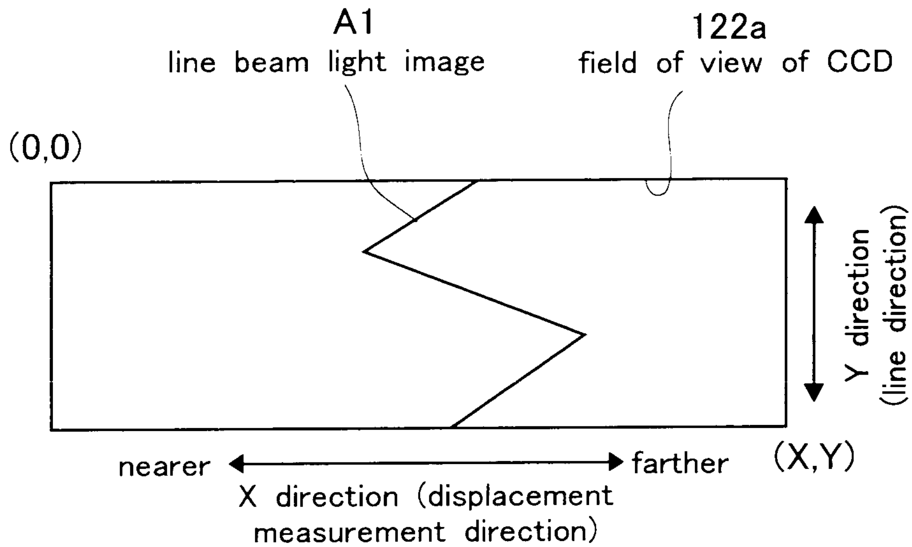
A view showing a mode of defining measurement object ranges

Fig. 5



A general flow chart schematically illustrating the operation of the displacement measurement by the sensor main unit

Fig. 6



A view illustrating an image
captured by the CCD incorporated in the sensor head unit

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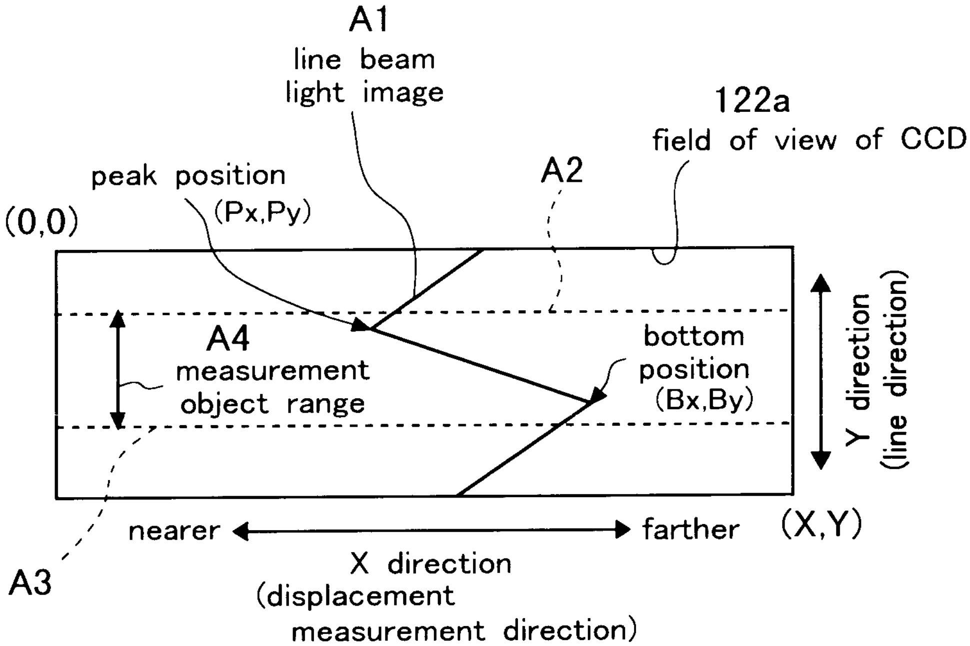
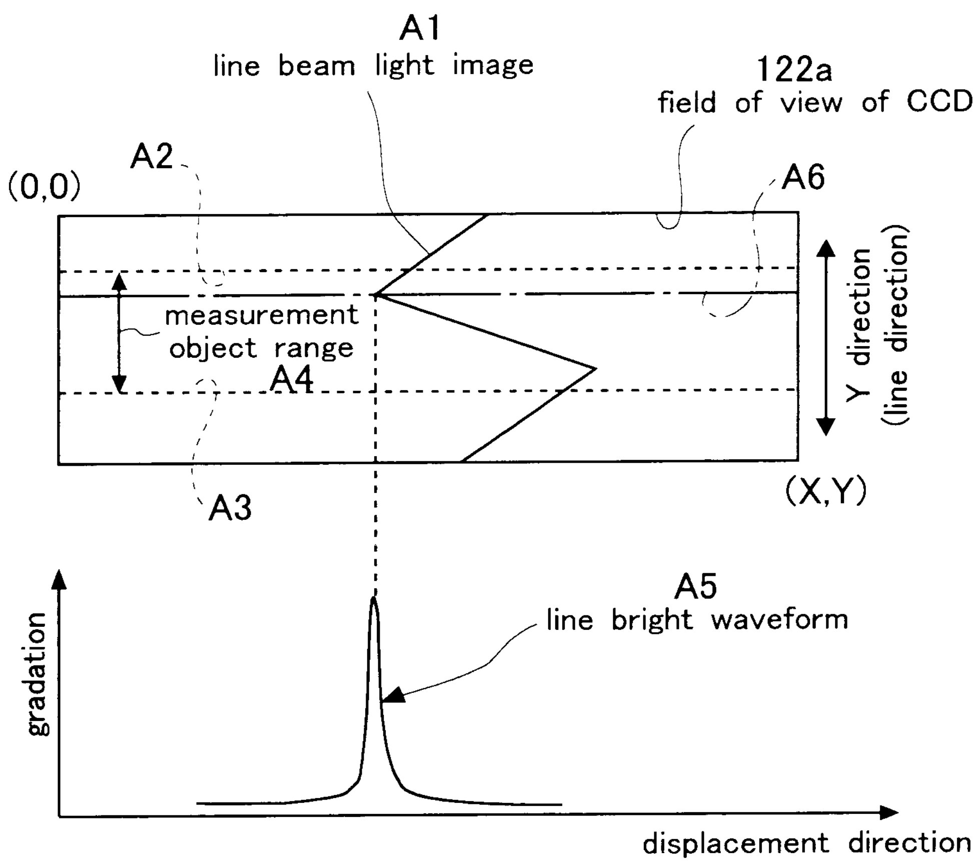
Fig. 7



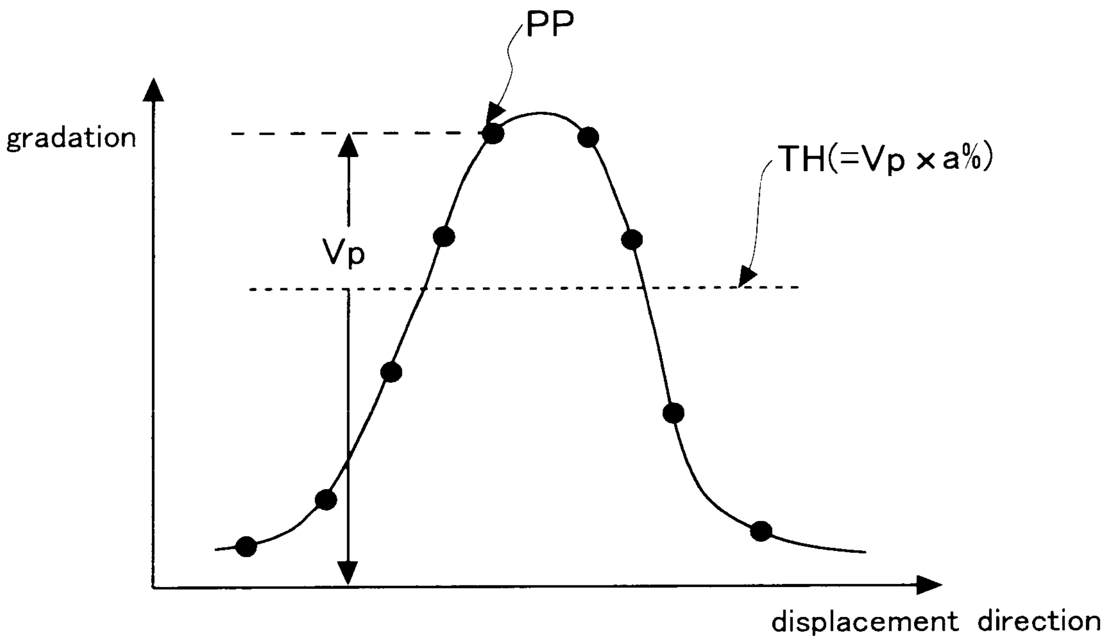
A view illustrating the process of
extracting measurement points in a measurement object range

Fig. 8



A view illustrating the relationship
between the line bright waveform and the image captured by the CCD

Fig. 9



An illustrative view showing the process of determining the threshold value

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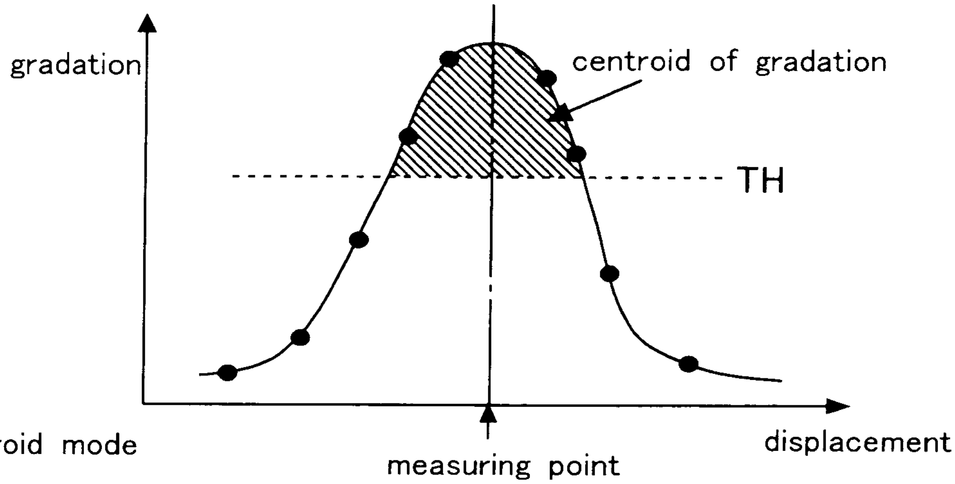
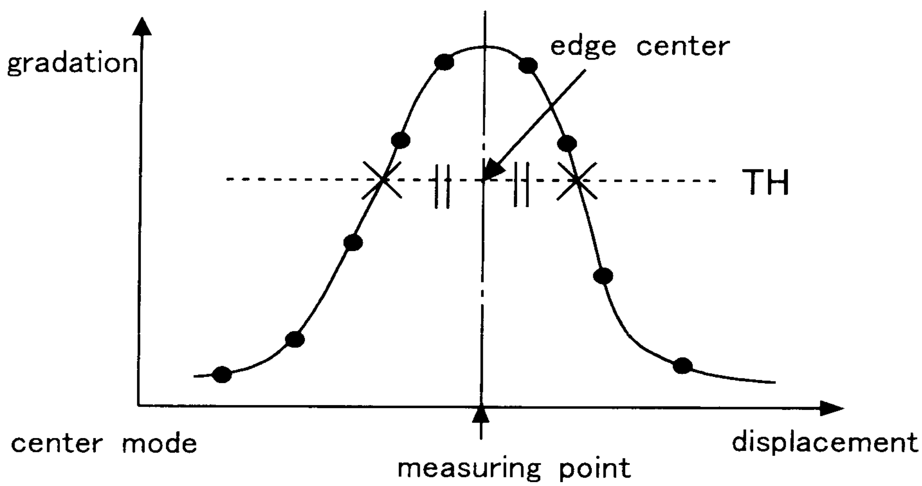
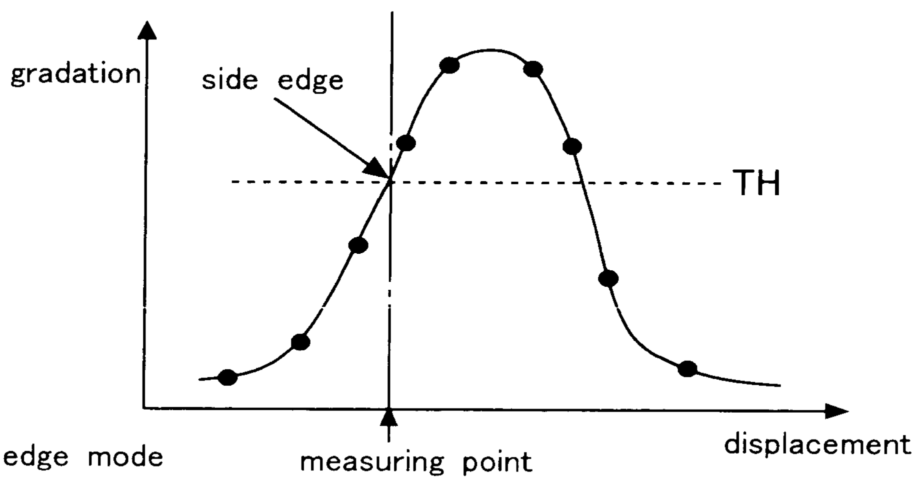
Fig. 10



(a) centroid mode



(b) edge center mode



(c) side edge mode

An illustrative view showing the process
<u>of extracting the measuring point coordinate</u>

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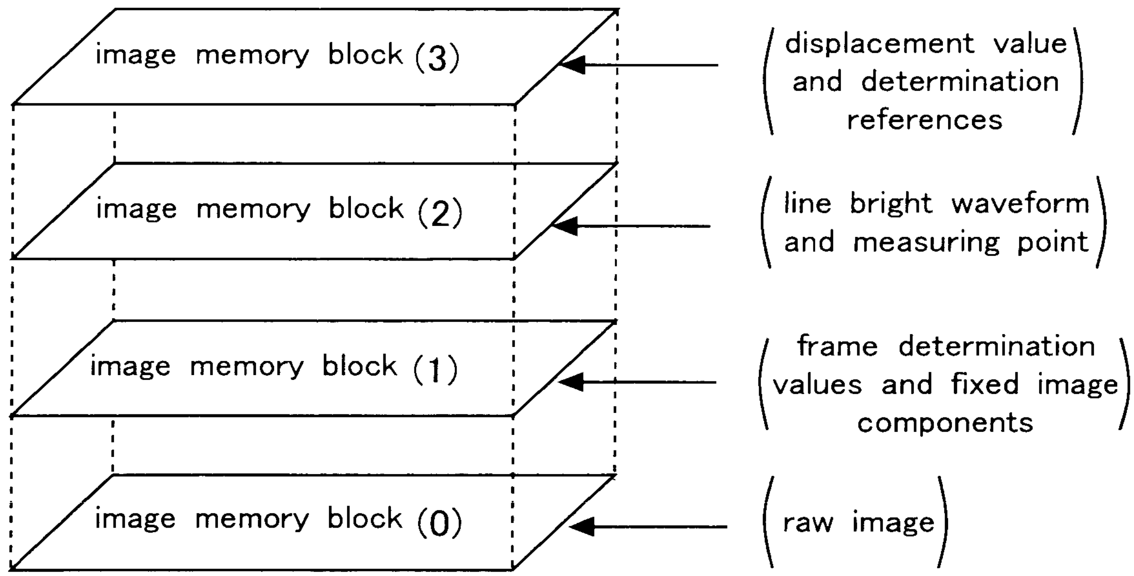
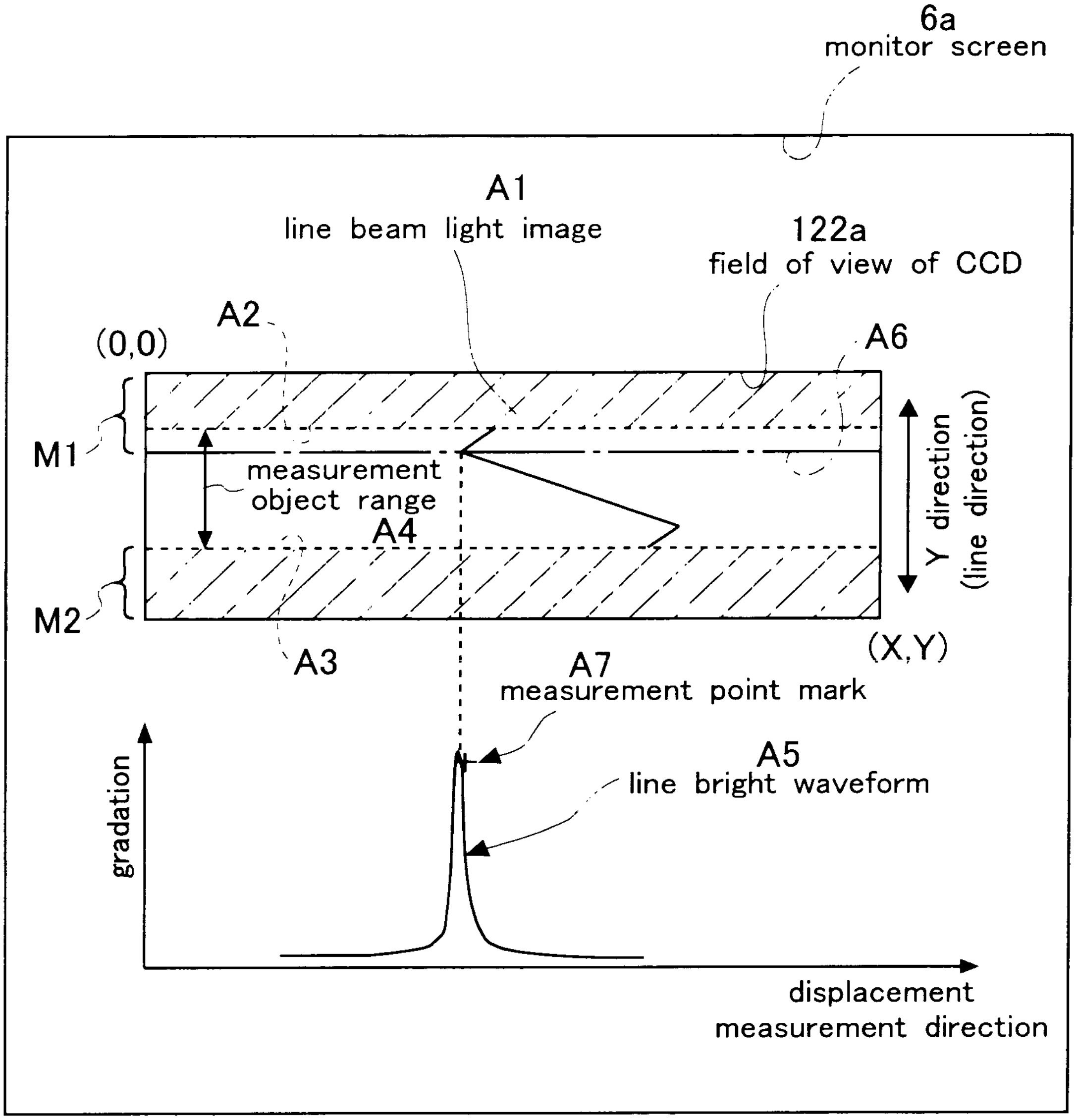
Fig. 11



An illustrative view showing the process of generating the monitor display

Fig. 12



A view showing an exemplary monitor display showing the relationship between the image captured by the CCD and line bright waveform

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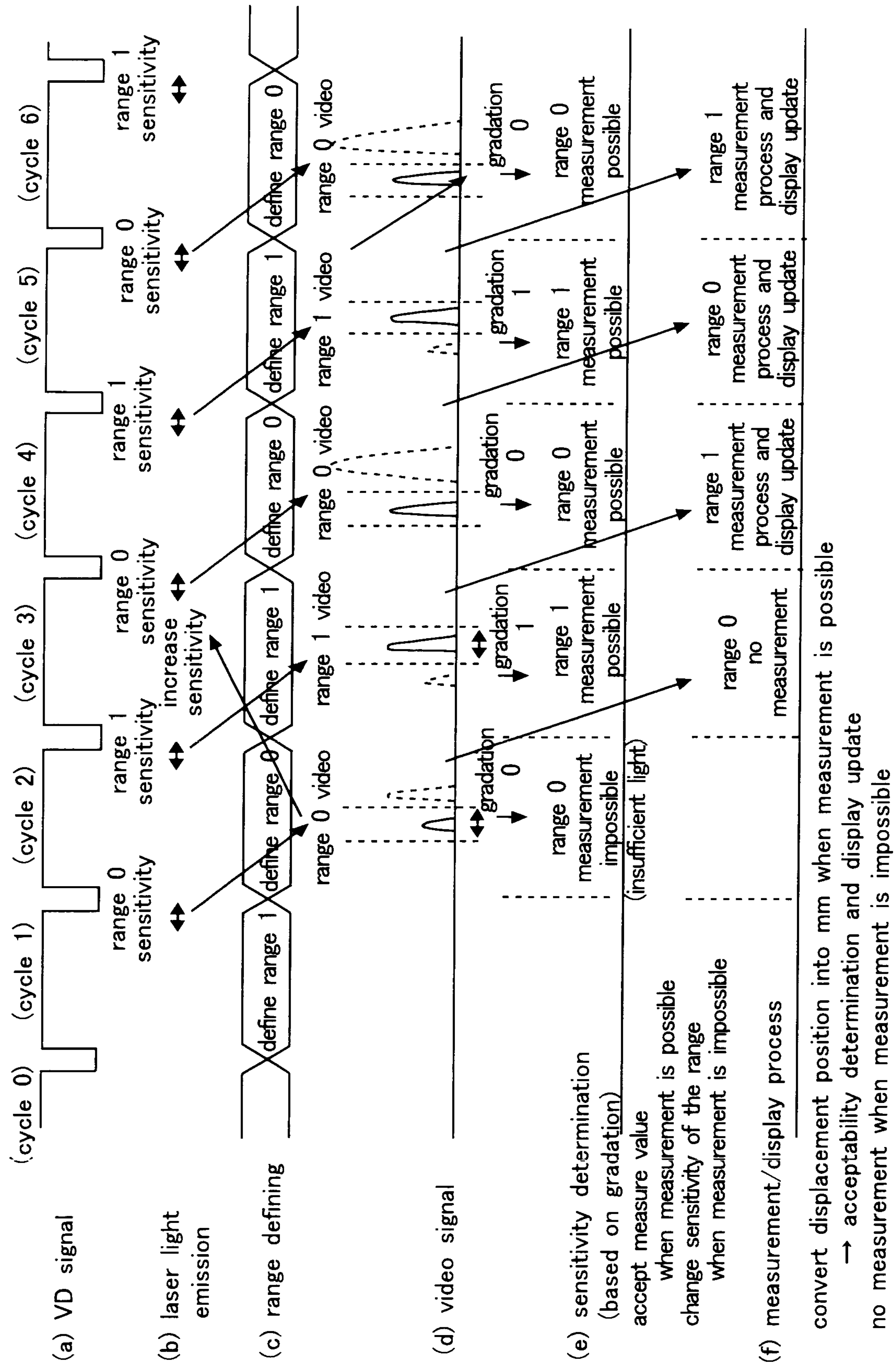
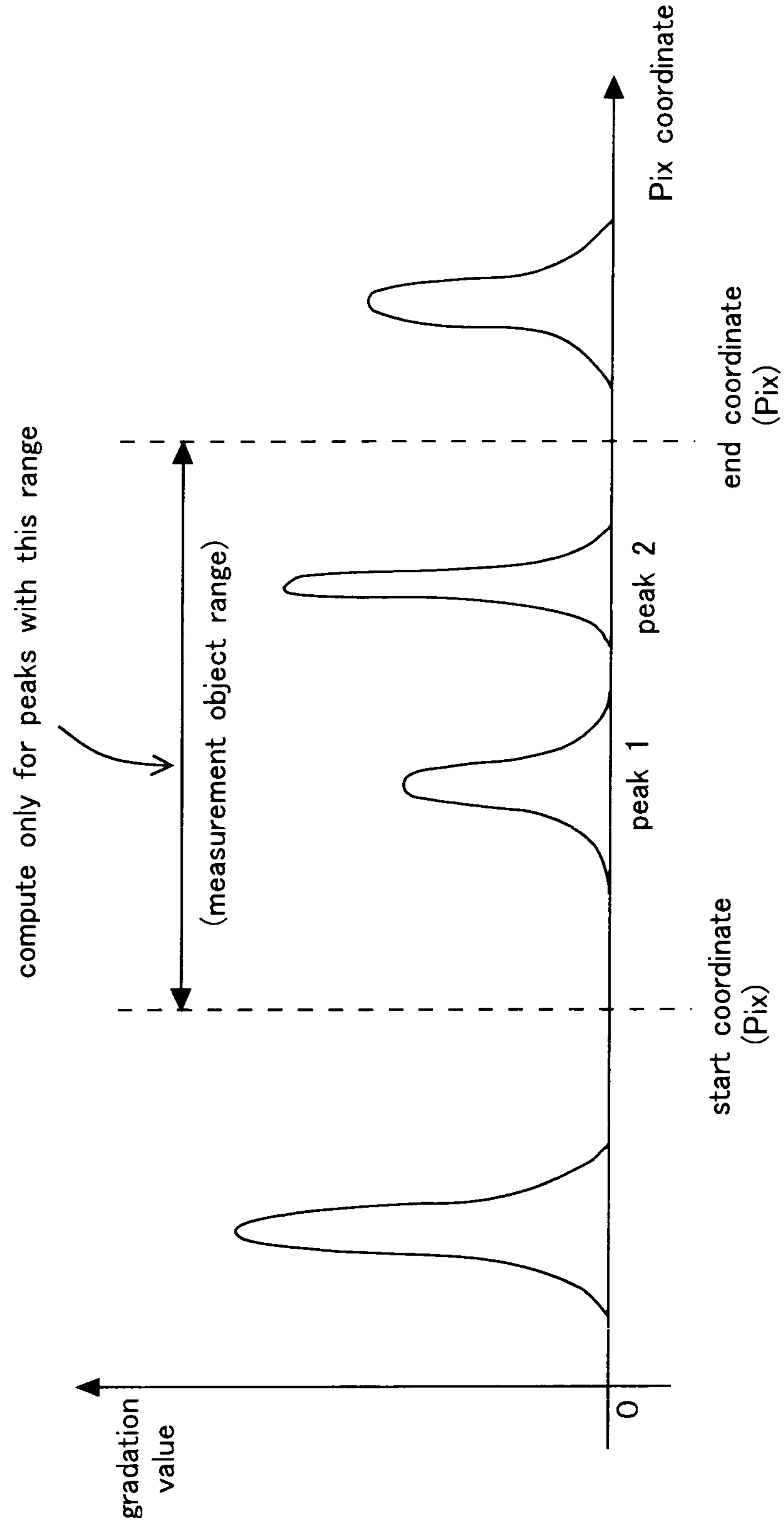
Fig.13



A time chart showing the gradation adjustment process for each range

37480

Fig.14



A view illustrating the relationship between the line bright waveform and measurement object range

Title: VISUAL DISPLACEMENT SENSOR
Inventor(s): Tatsuya Matsunaga, et al.
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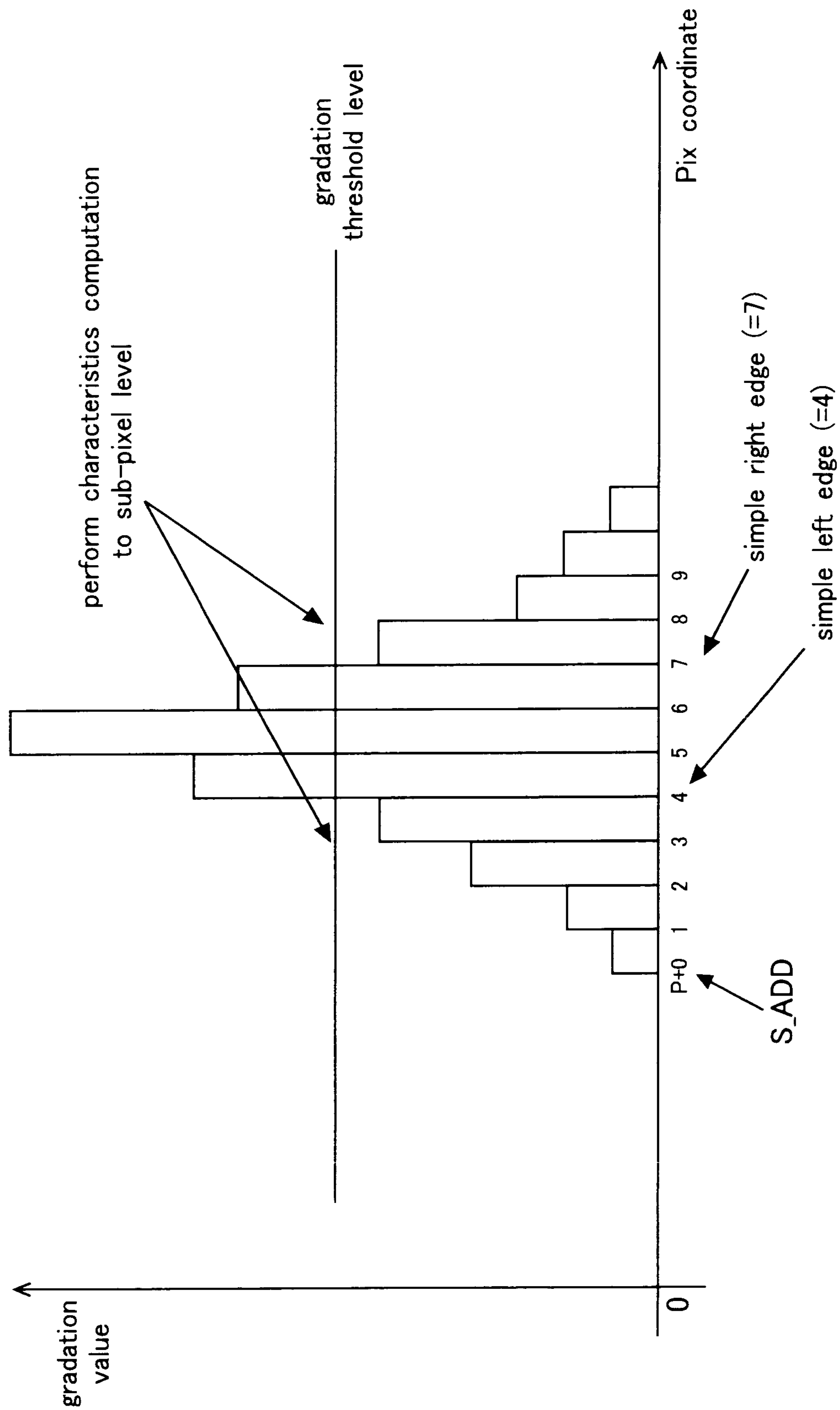
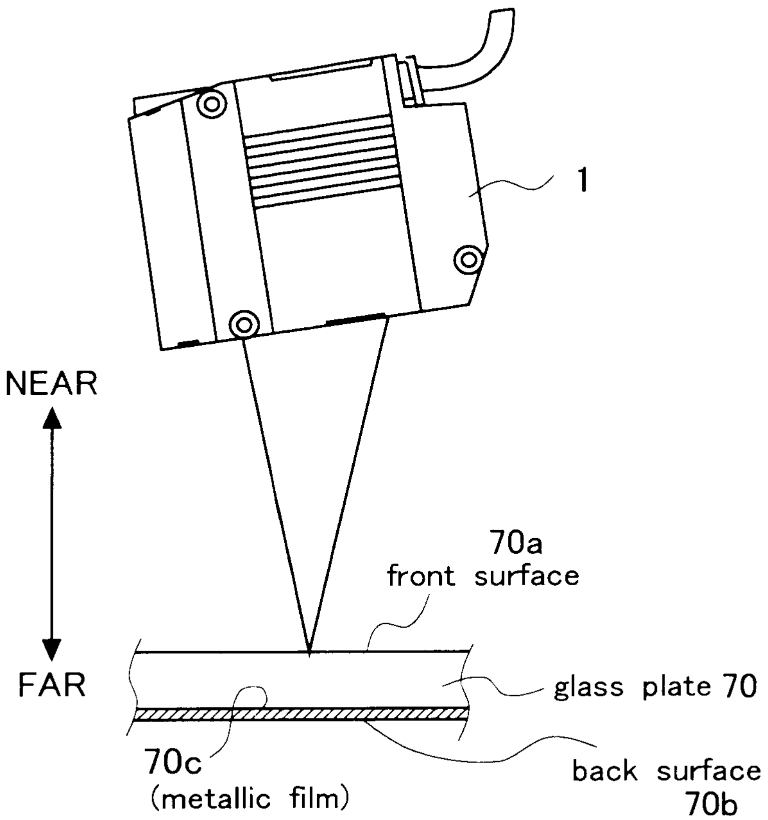
Fig. 15



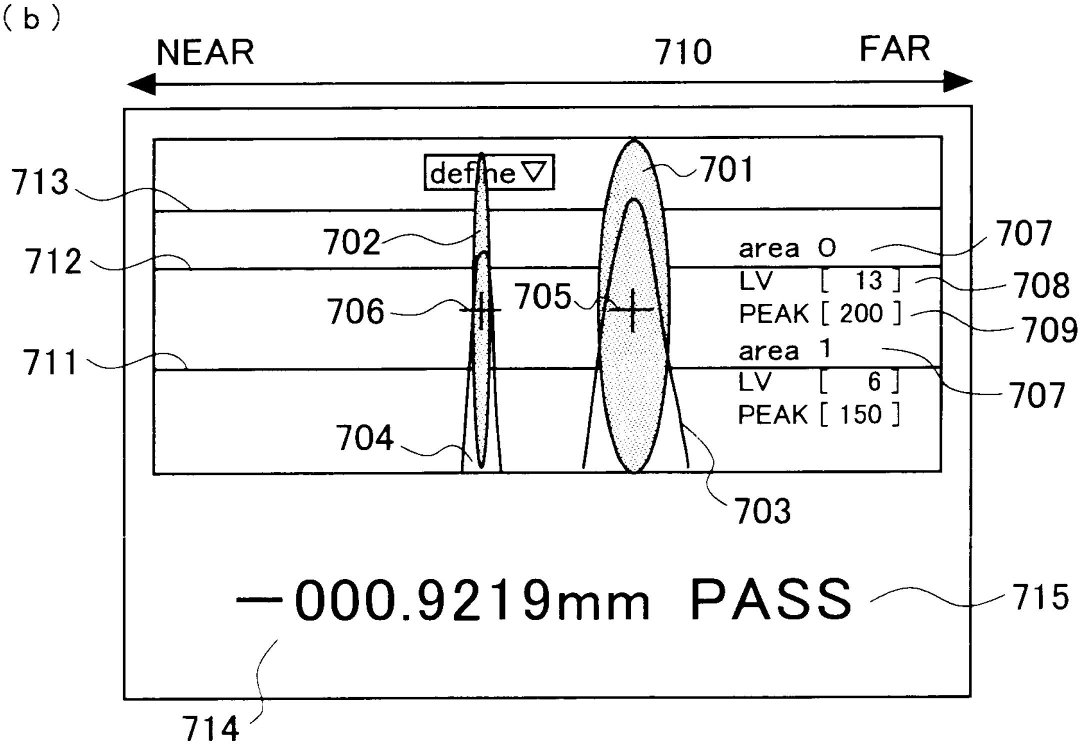
A view illustrating the characteristic computation for determining measurement point coordinates

Fig. 16

(a)

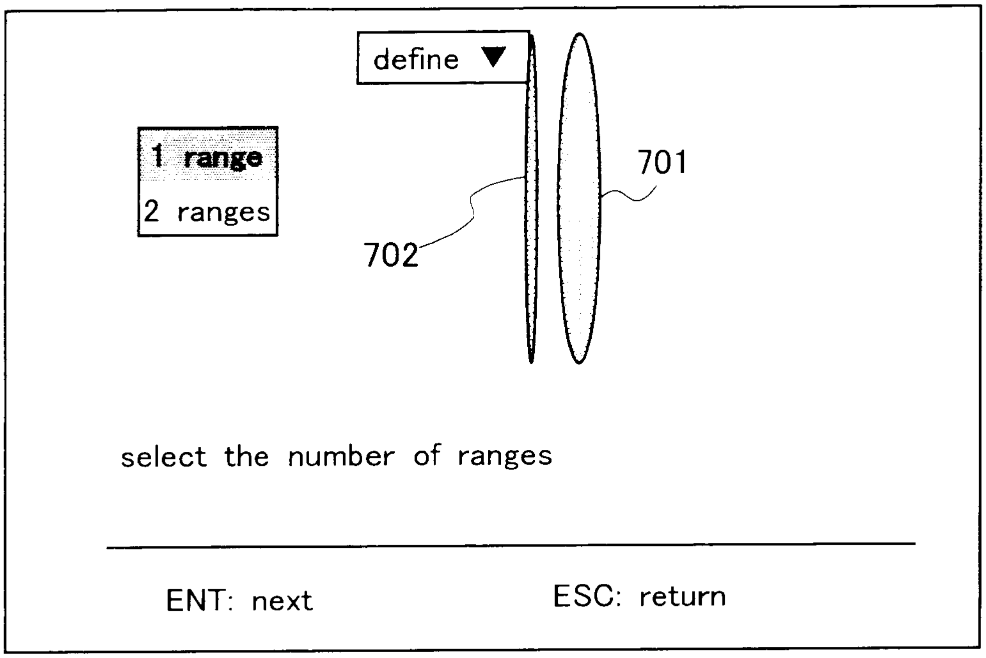


(b)

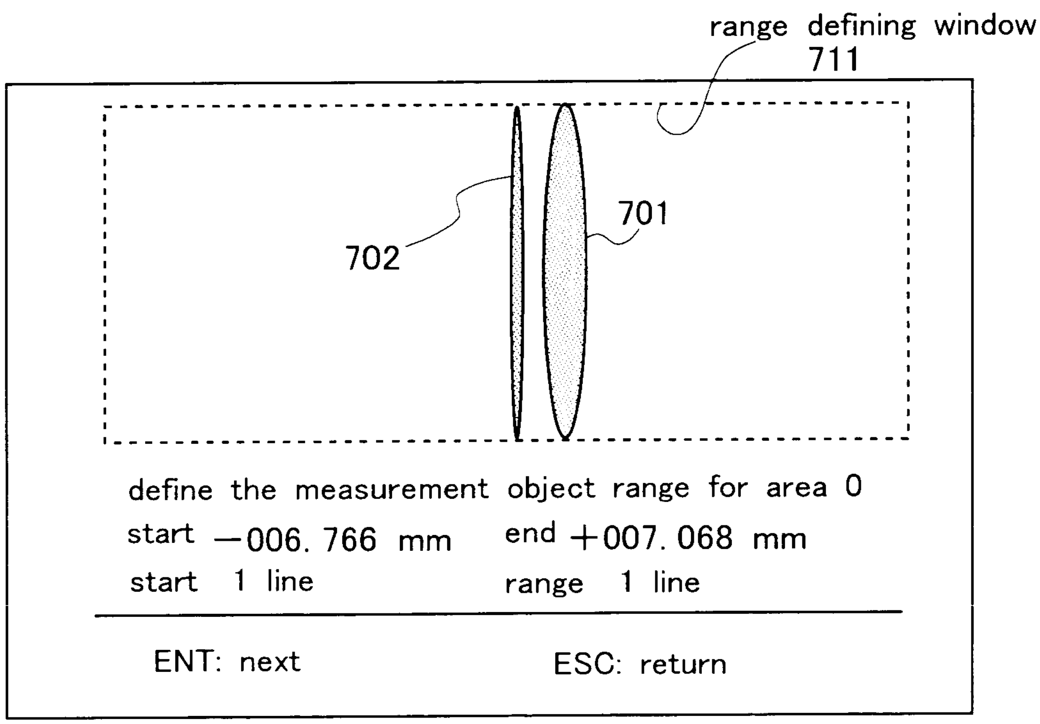


a view showing a conventional measurement result

Fig. 17



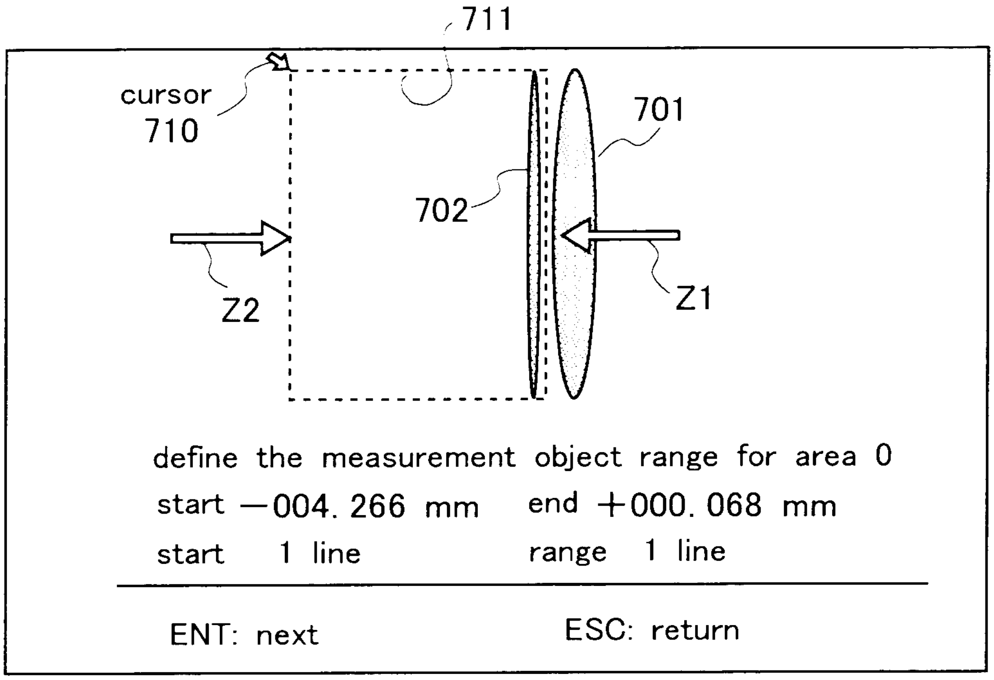
(a) selecting the number of ranges to be defined



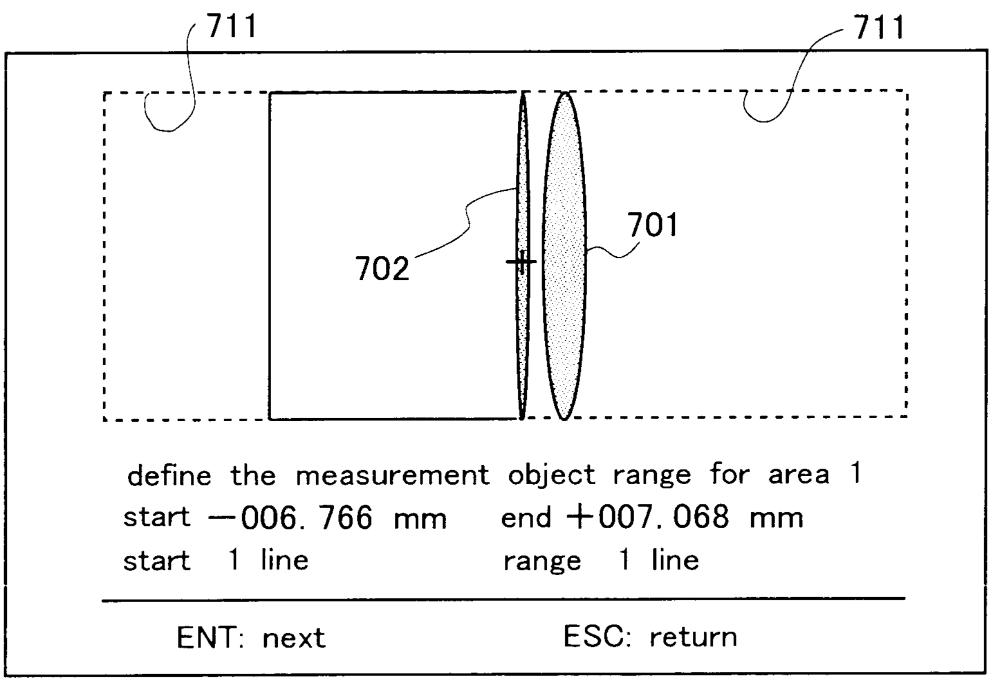
(b) defining measurement object range 0

A view illustrating the monitor screen when defining regions (part 1)

Fig. 18



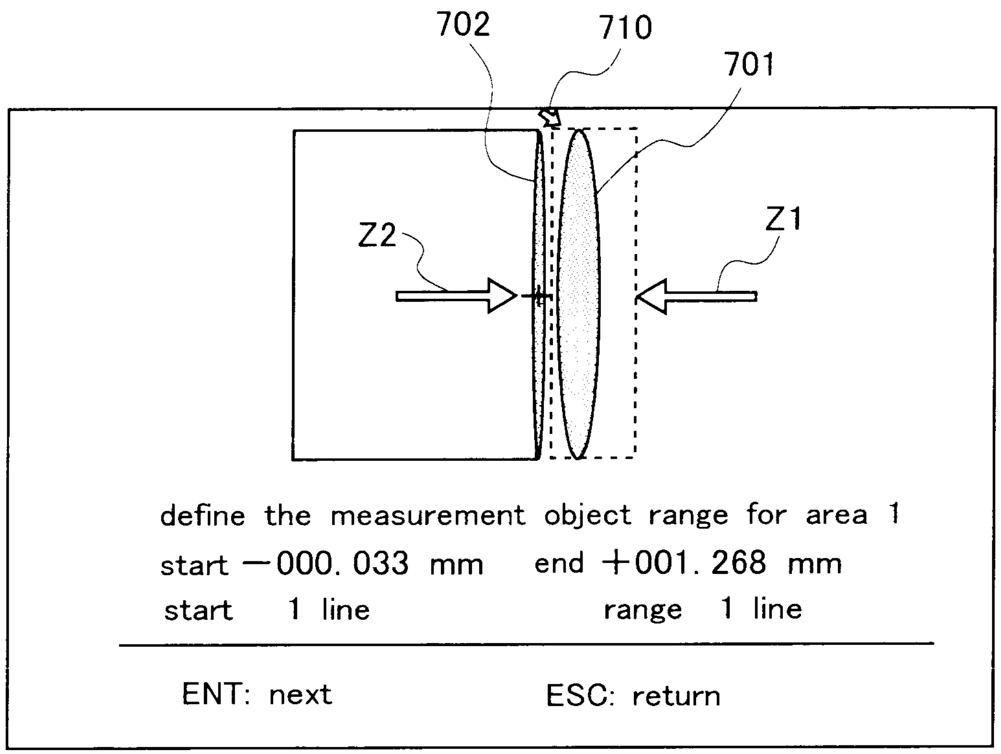
(a) defining measurement object range 0



(b) complete the defining of measurement object range 0 (acquire a relative reference position)

A view illustrating the monitor screen when defining regions (part 2)

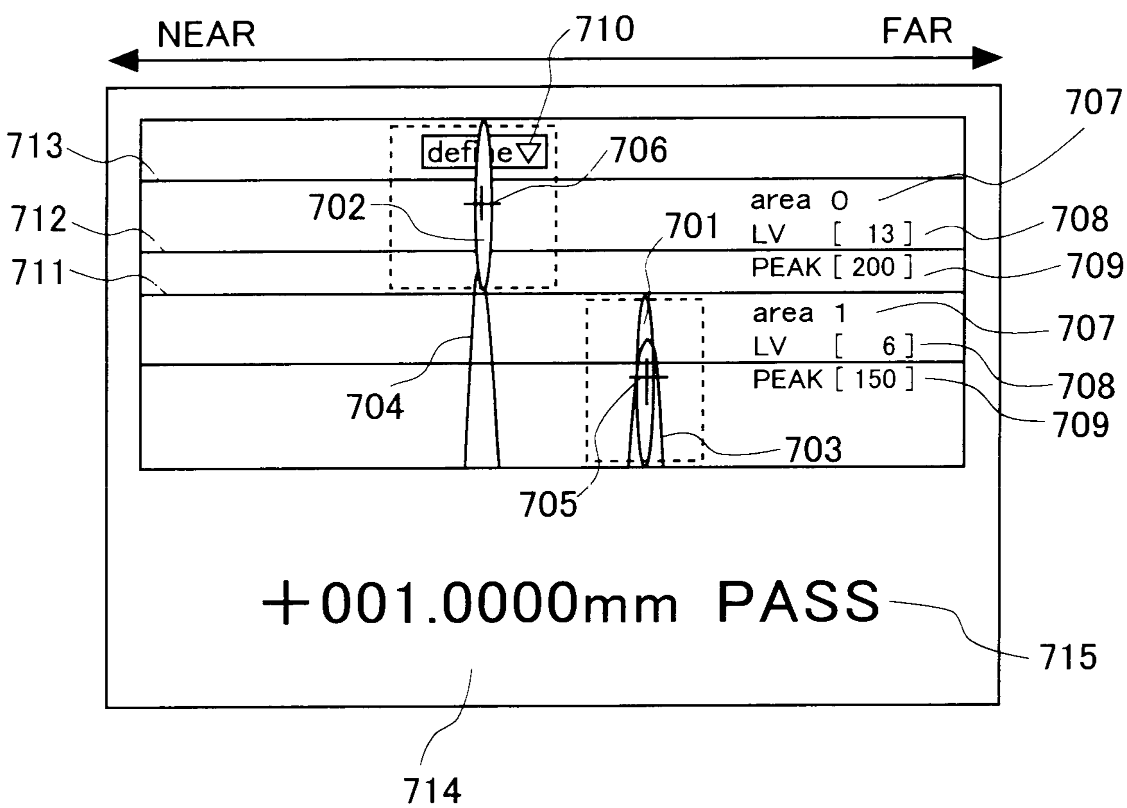
Fig. 19



defining measurement object range 1
→ select only the back surface
for the measurement object range

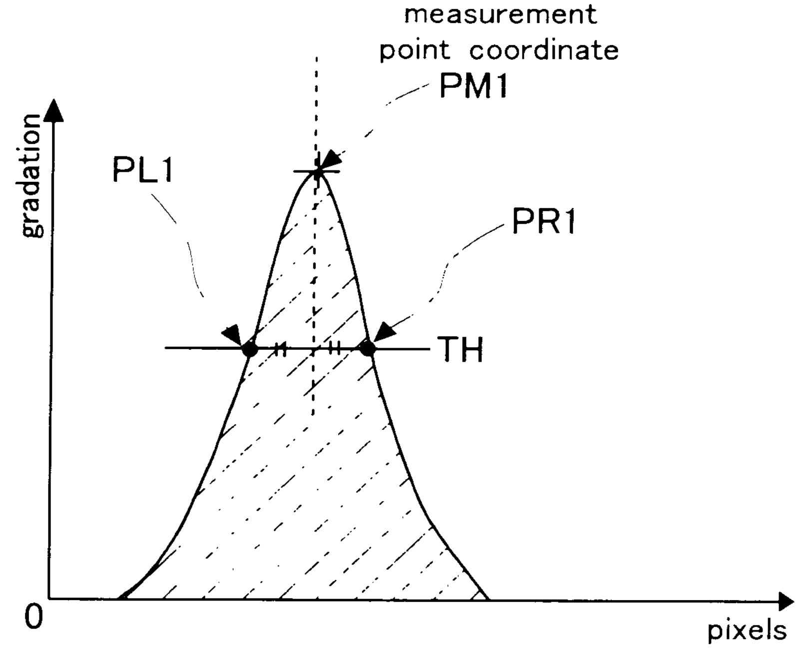
A view illustrating the monitor screen when defining regions (part 3)

Fig.20

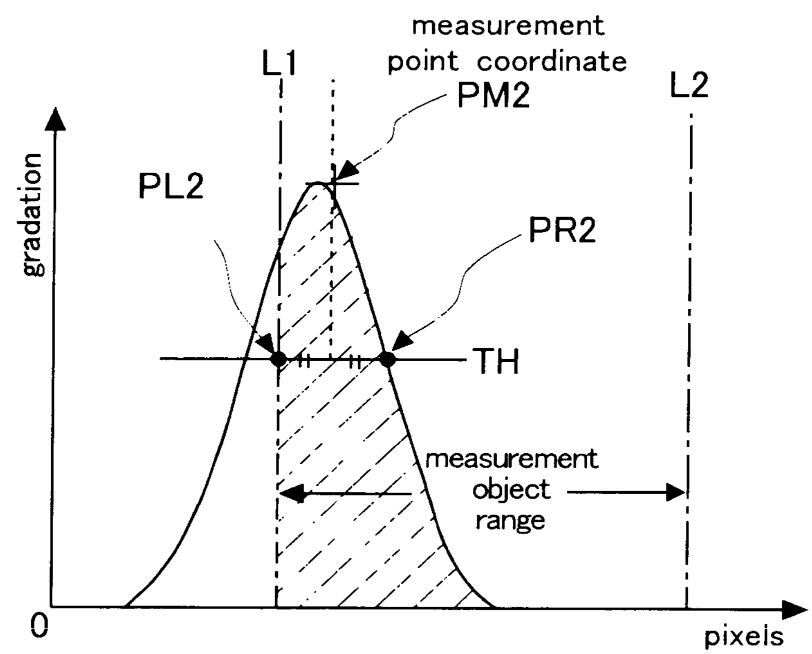


A view illustrating the monitor screen at the time of measurement after two measurement object ranges are defined

Fig.21



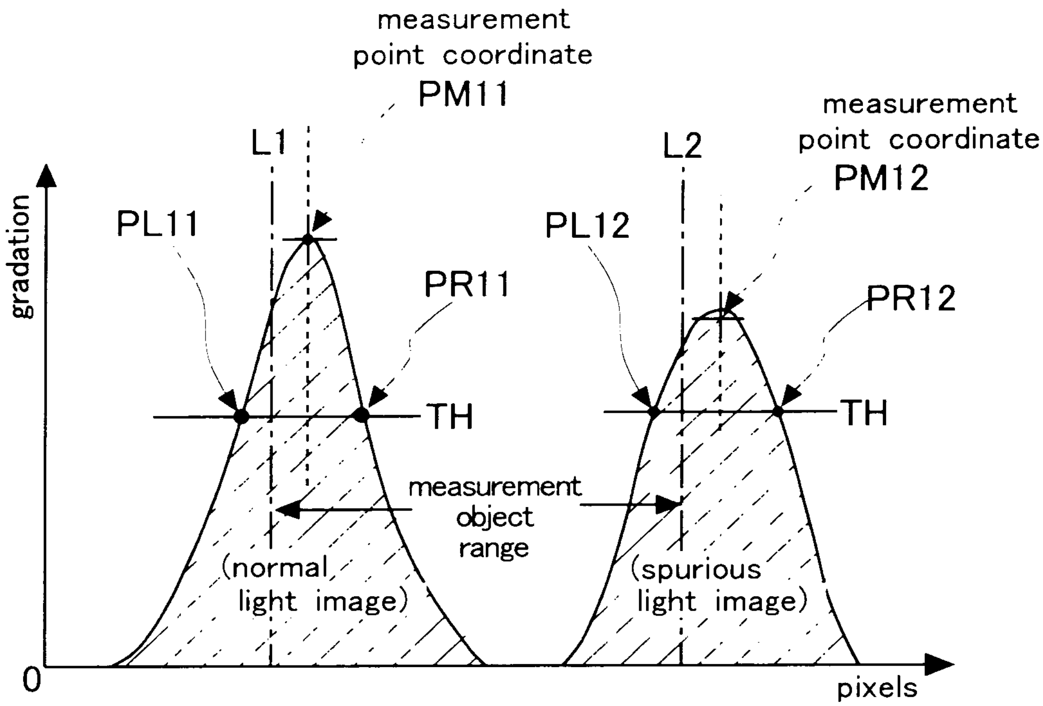
(a) measurement point coordinate extracted from the input image



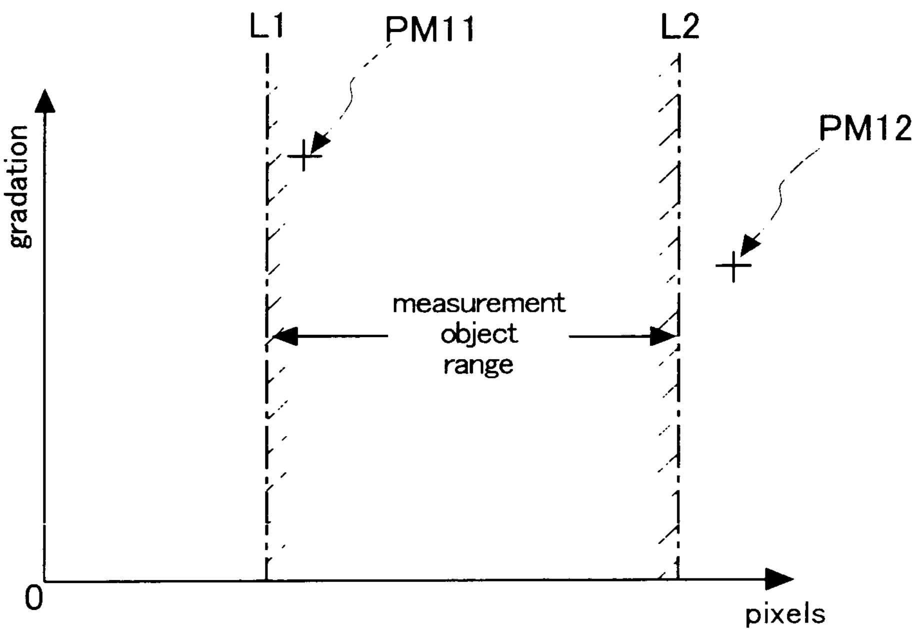
(b) measurement point coordinate extracted from the masked image

A view illustrating the problem with the process of extracting a measurement point coordinate using a masked image

Fig.22



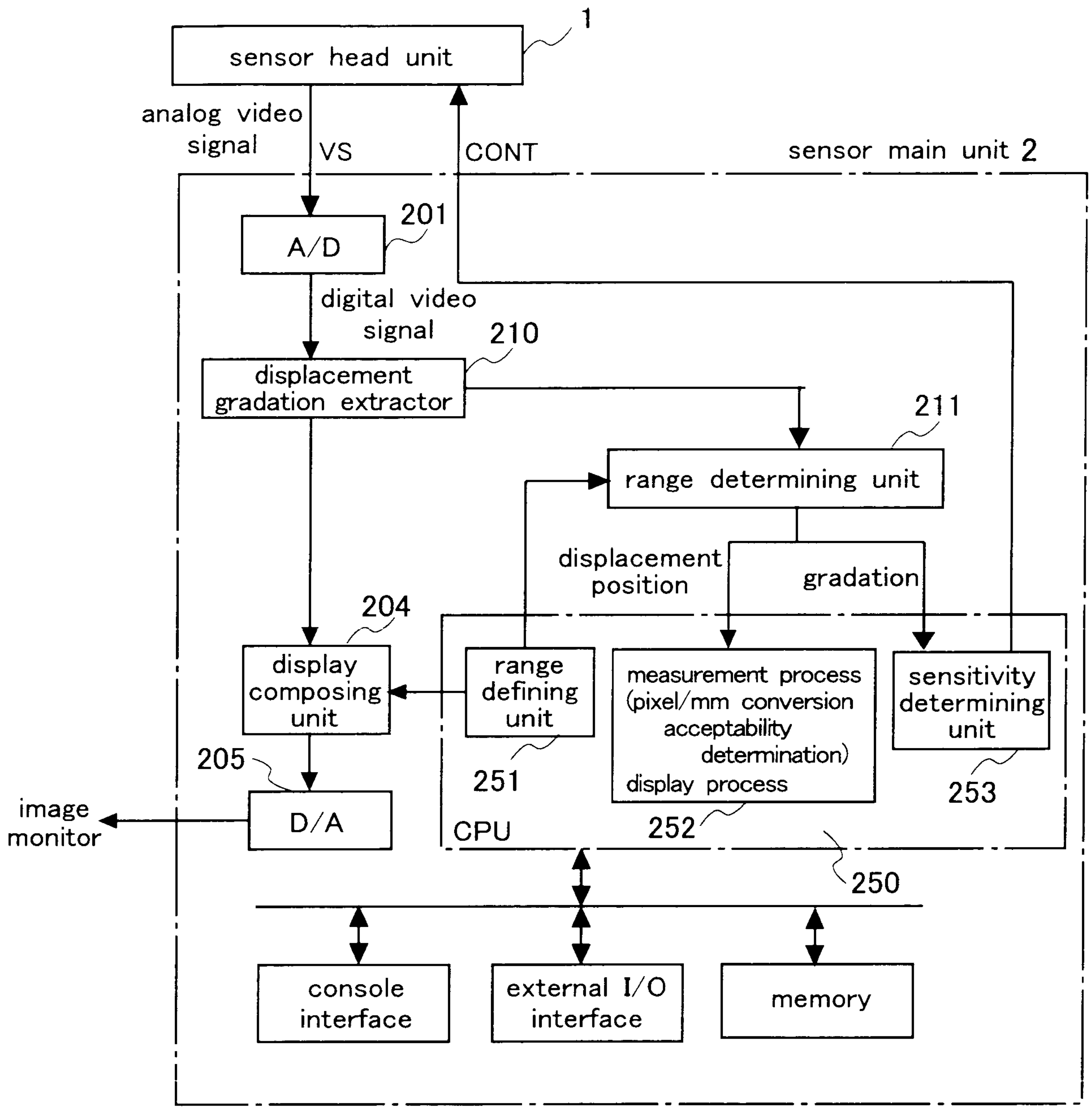
(a) provisional decision of measurement point coordinates



(b) formal decision of measurement point coordinates

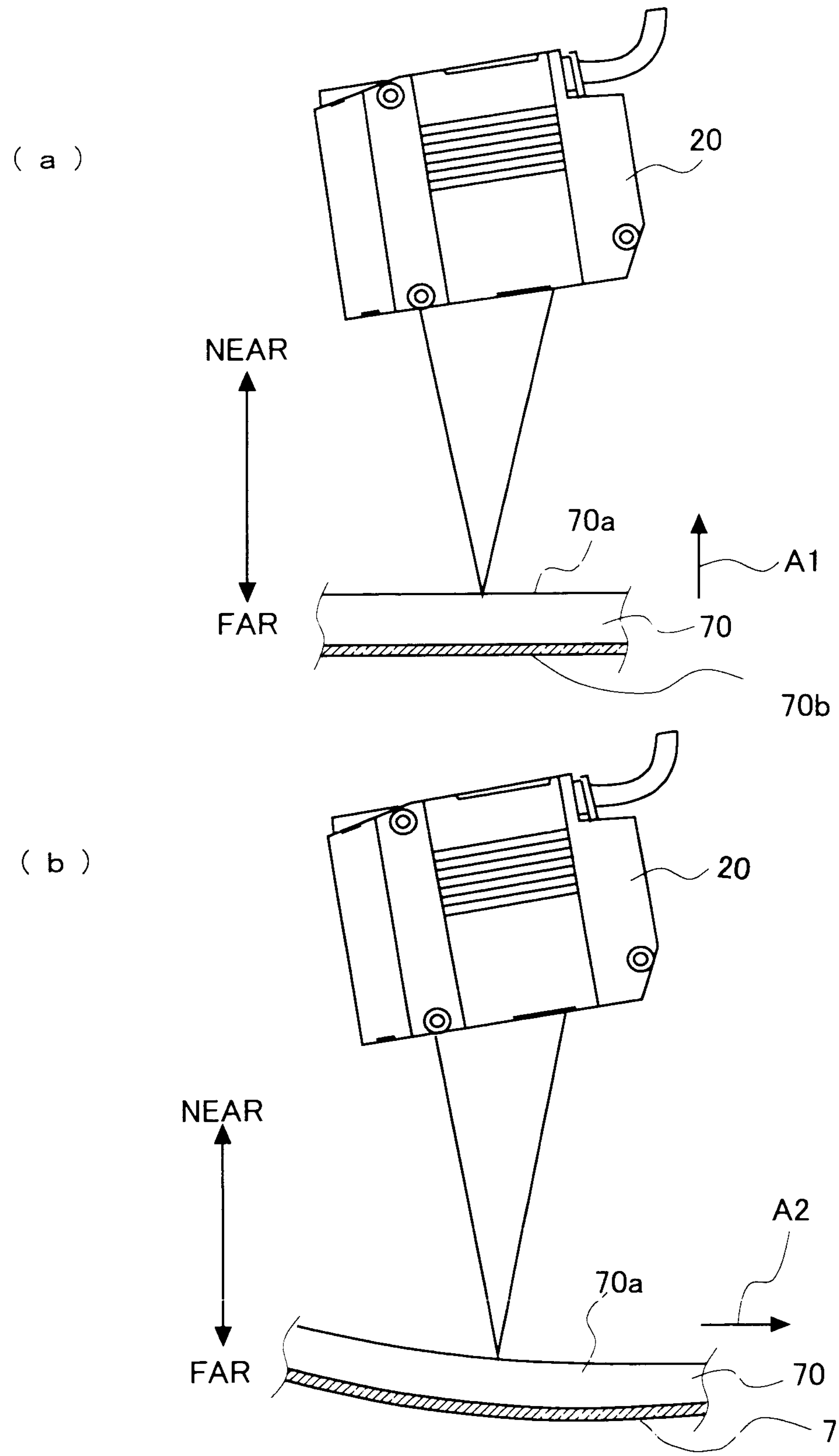
A view illustrating the second embodiment of the process of extracting a measurement point coordinate using a masked image

Fig.23



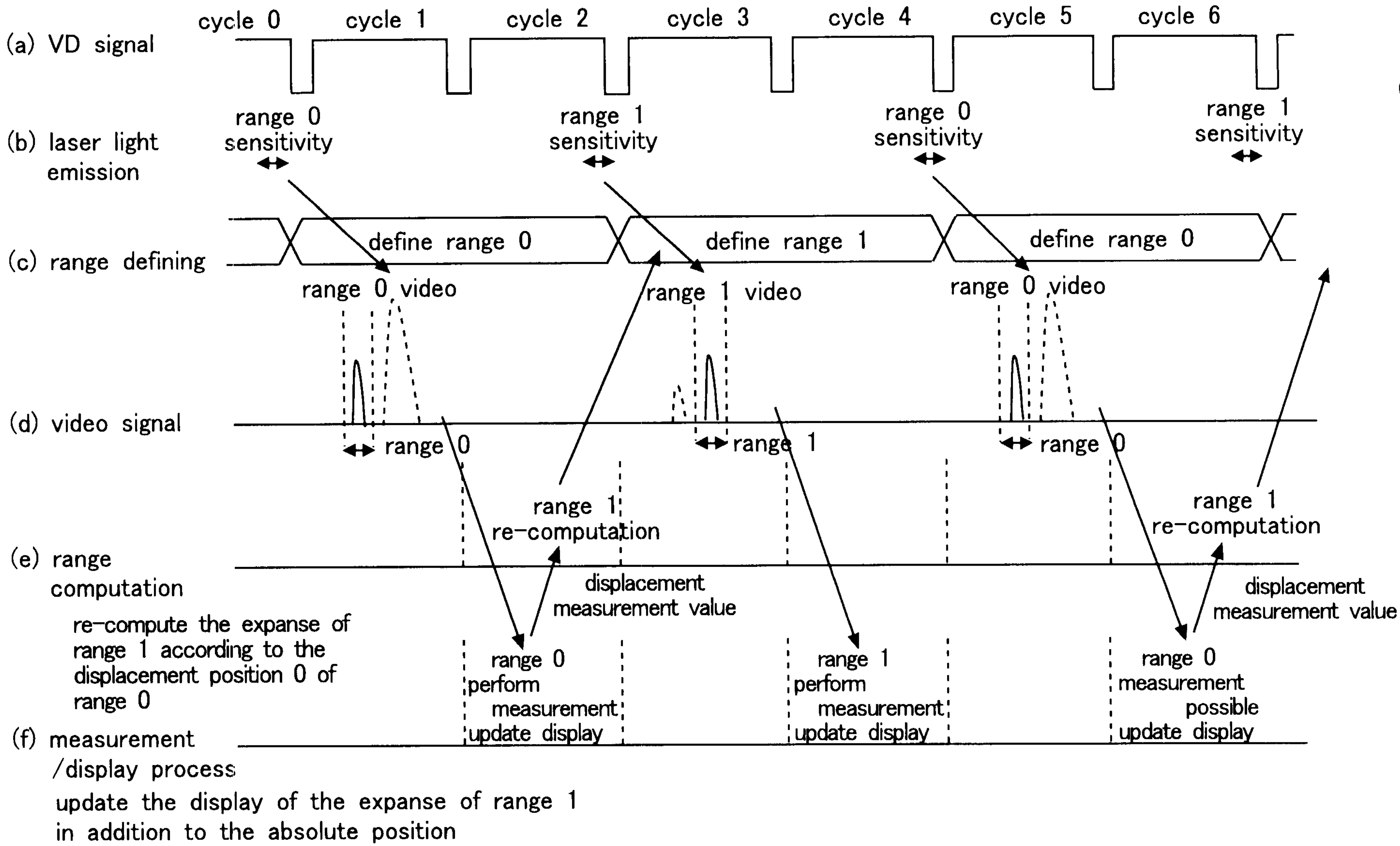
A block diagram (part 2)
showing the functional internal structure of the sensor main unit

Fig.24



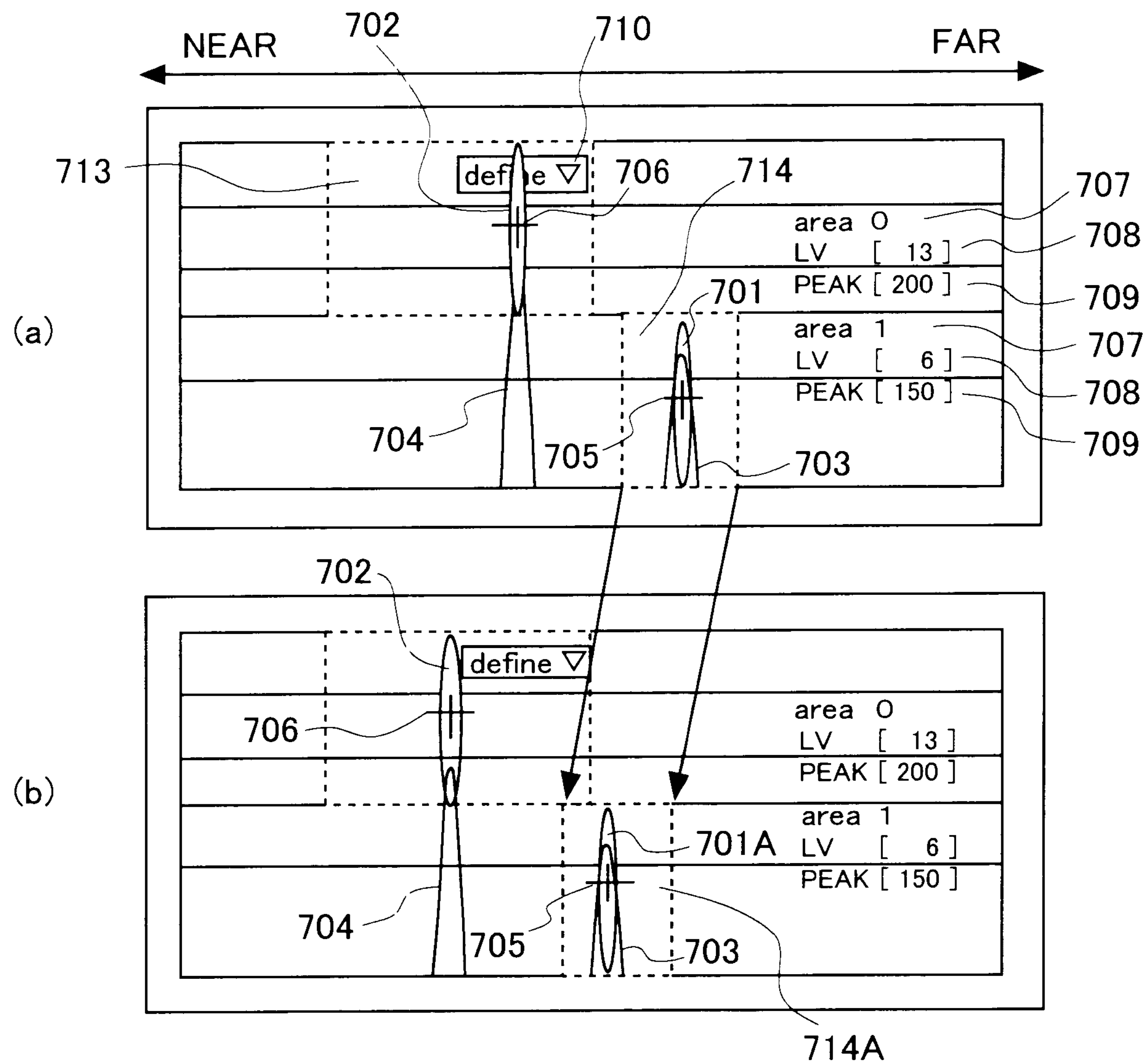
A view showing a mode of vertical changes in a measurement point

Fig.25



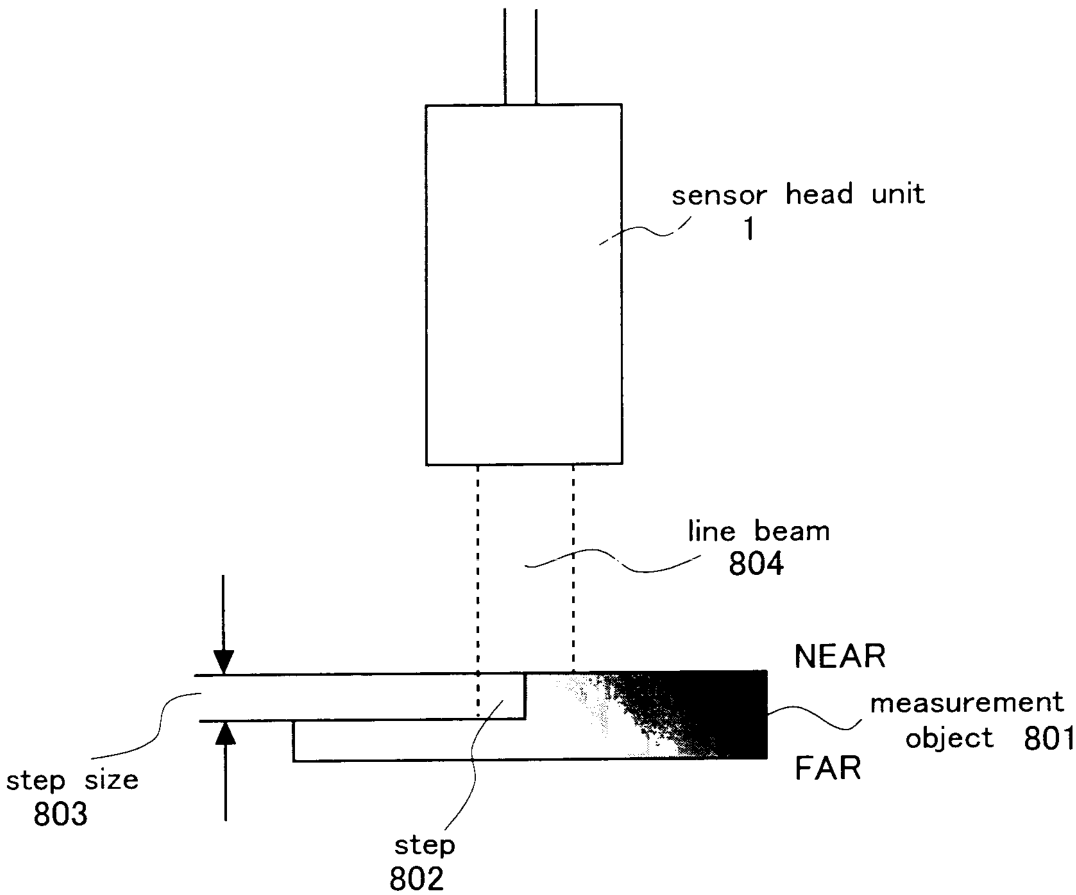
A time chart showing the process
<u>of tracking defined regions to the vertical change in the measurement point</u>

Fig.26



A view showing the monitor screen
before and after the vertical change in the measurement point

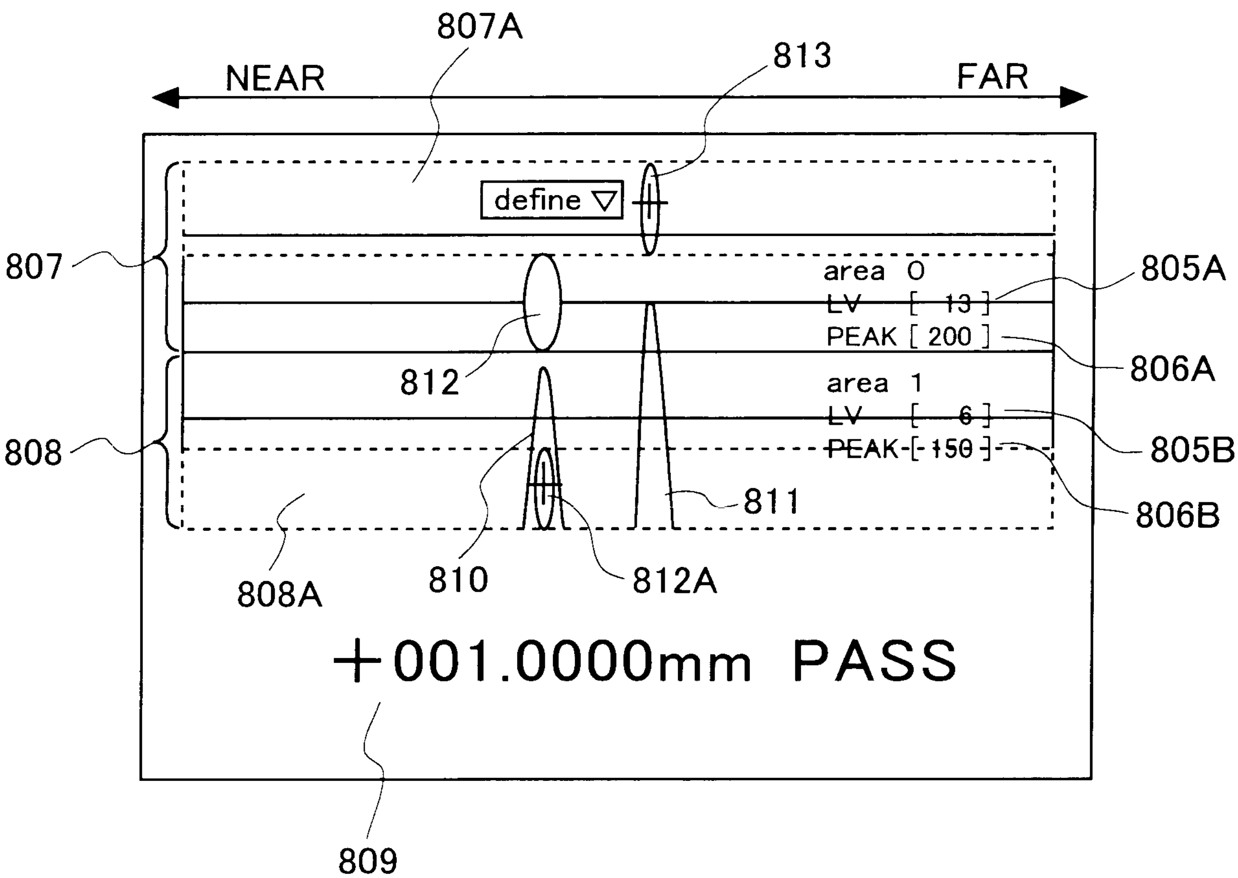
Fig.27



A view illustrating the positional relationship
between the sensor and measurement object when measuring a step

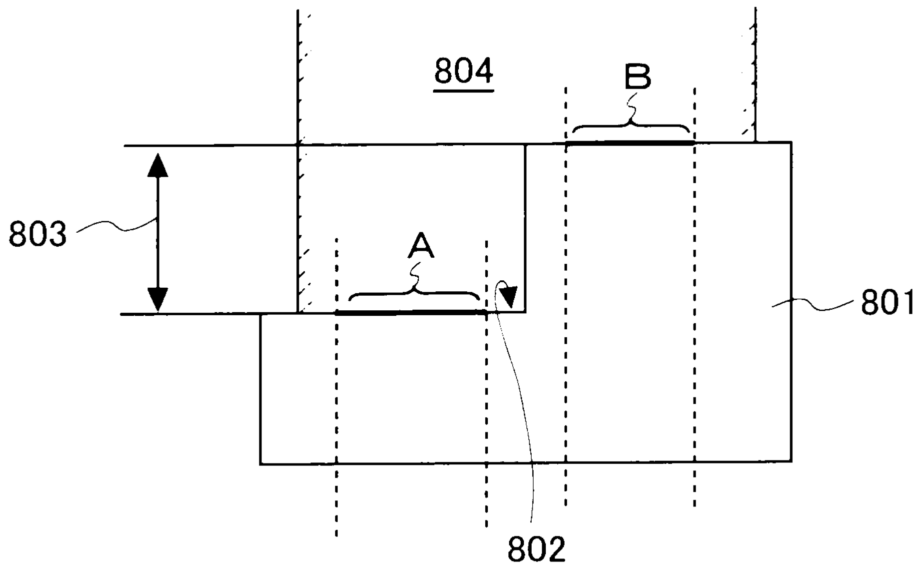
09/037430

Fig.28

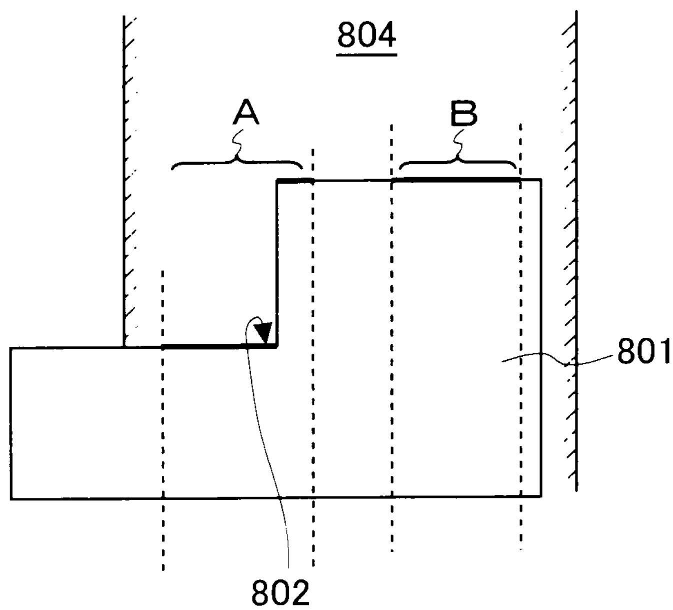


A view showing the monitor screen for the measurement of a step

Fig.29



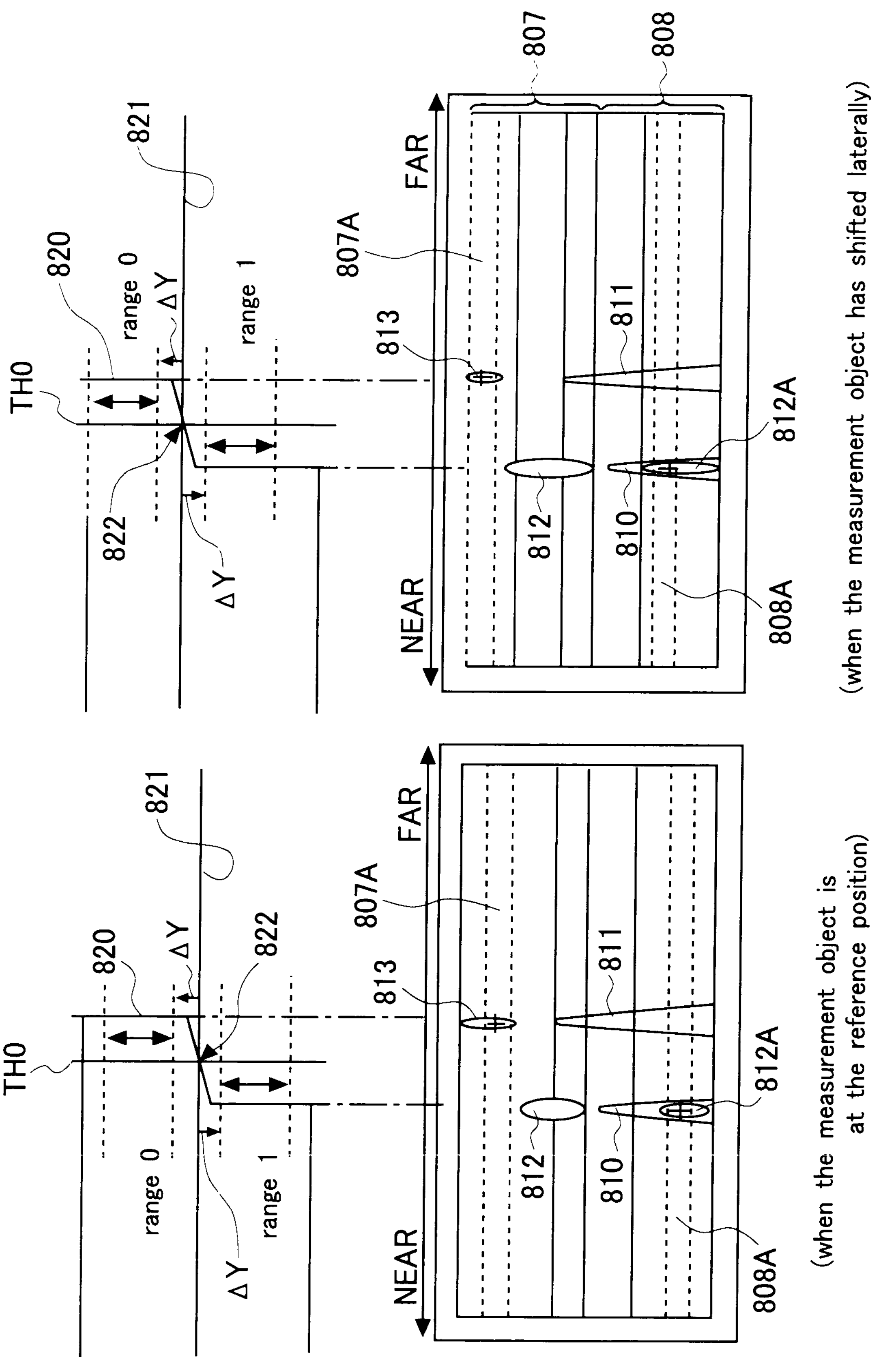
(a) when the measurement object is at the reference position



(b) when the measurement object has shifted laterally

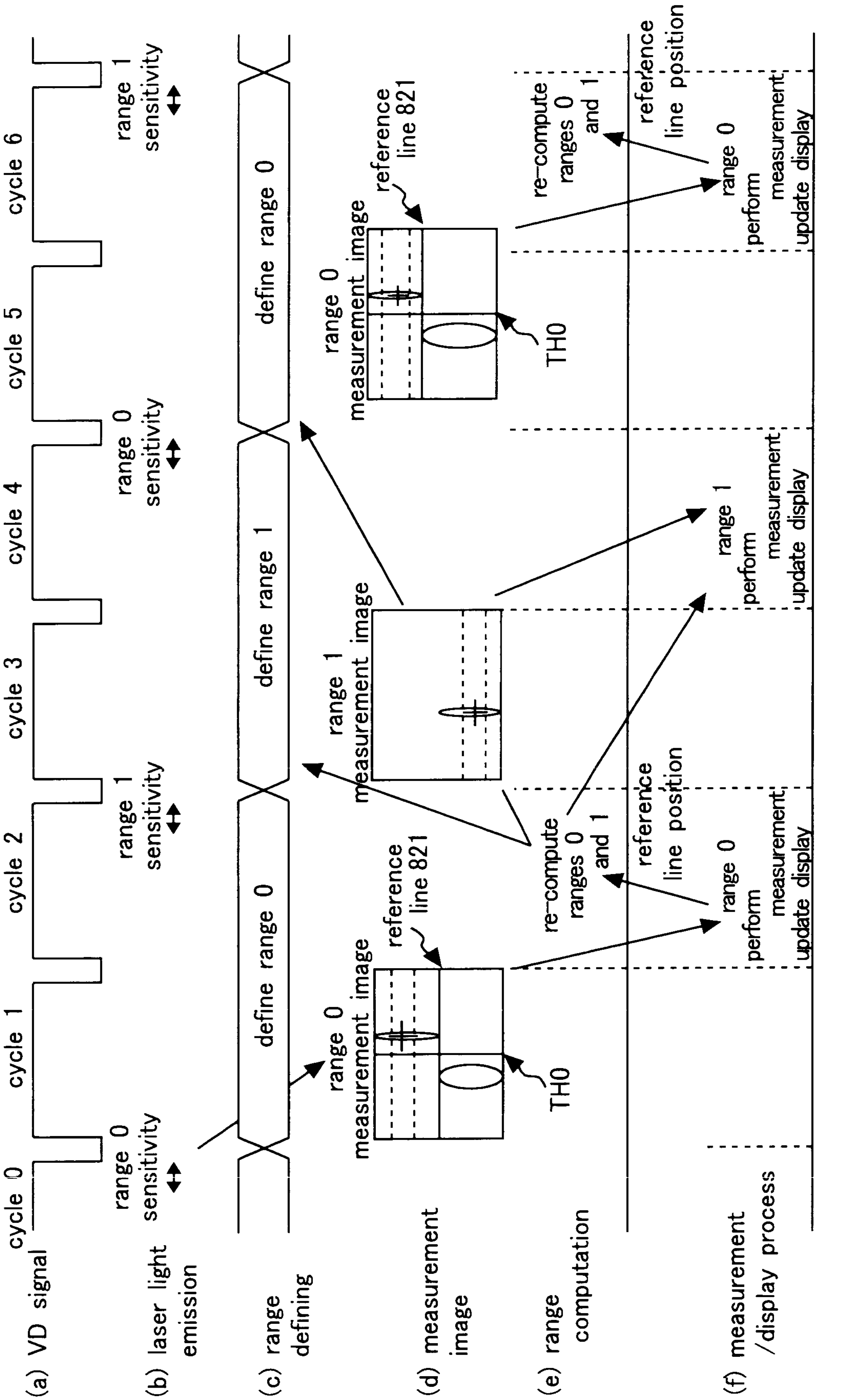
A view illustrating the problem associated with the lateral shifting of the measurement object when measuring a step

Fig.30



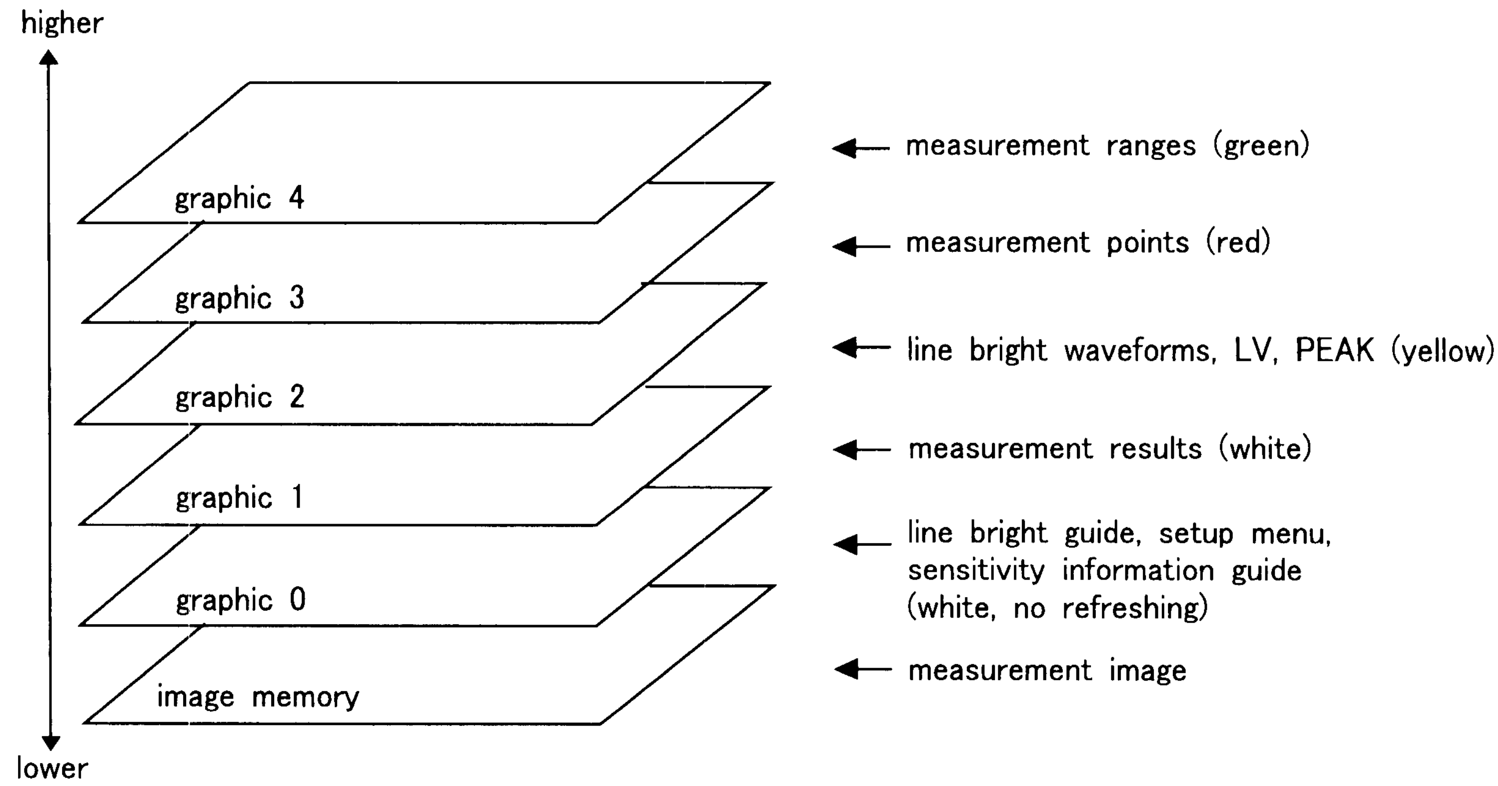
A view showing the control of tracking a lateral shift when measuring a step

Fig.31



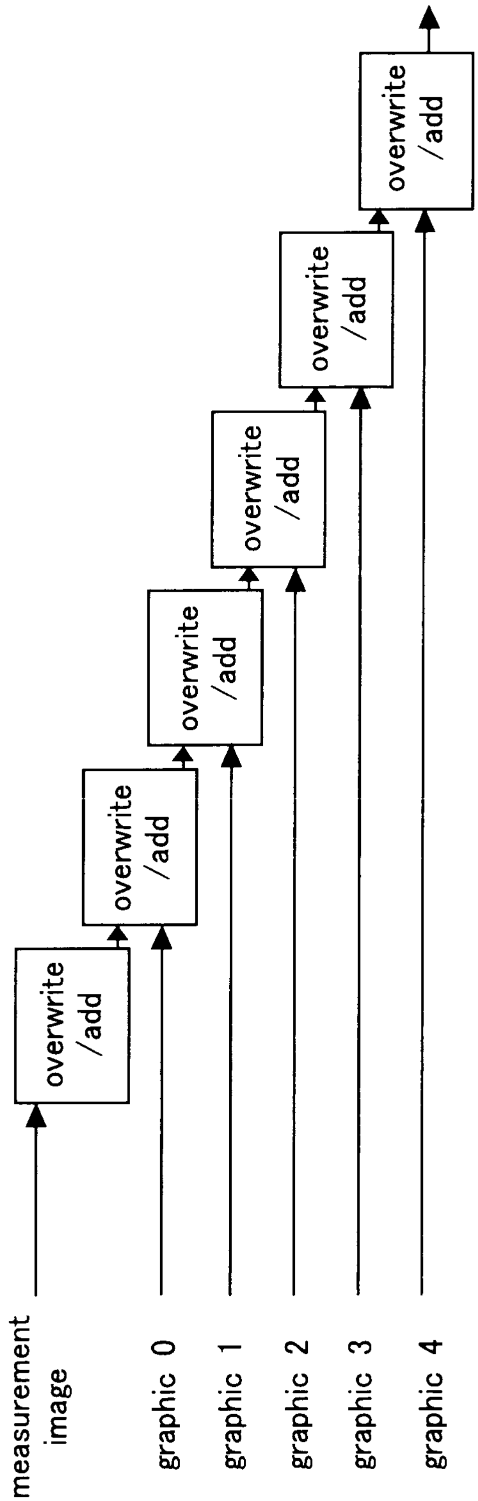
A time chart showing the flow of the control process of tracking a lateral shift when measuring a step

Fig.32



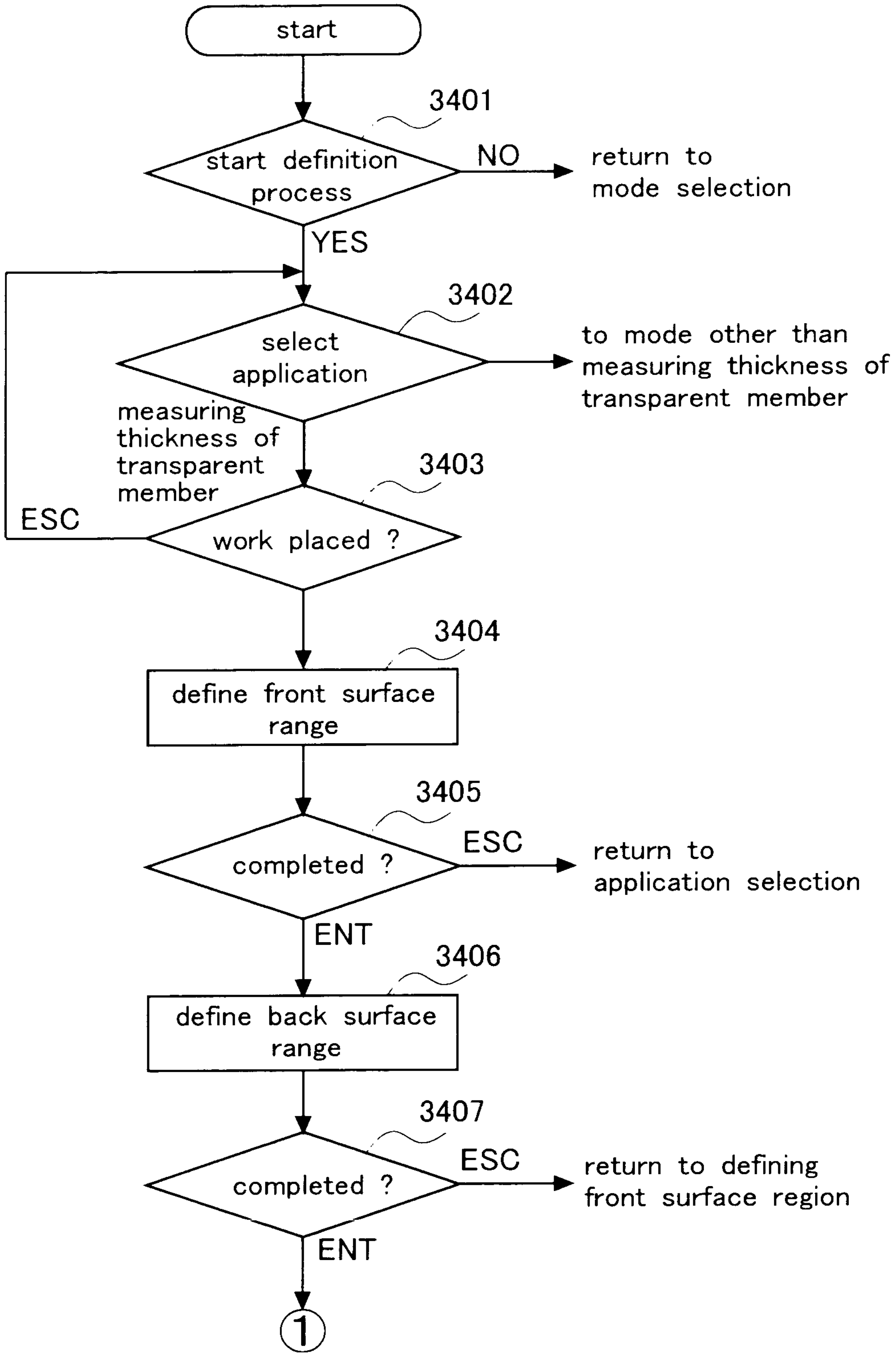
A view illustrating the process of composing a display for the image monitor (part 1)

Fig.33



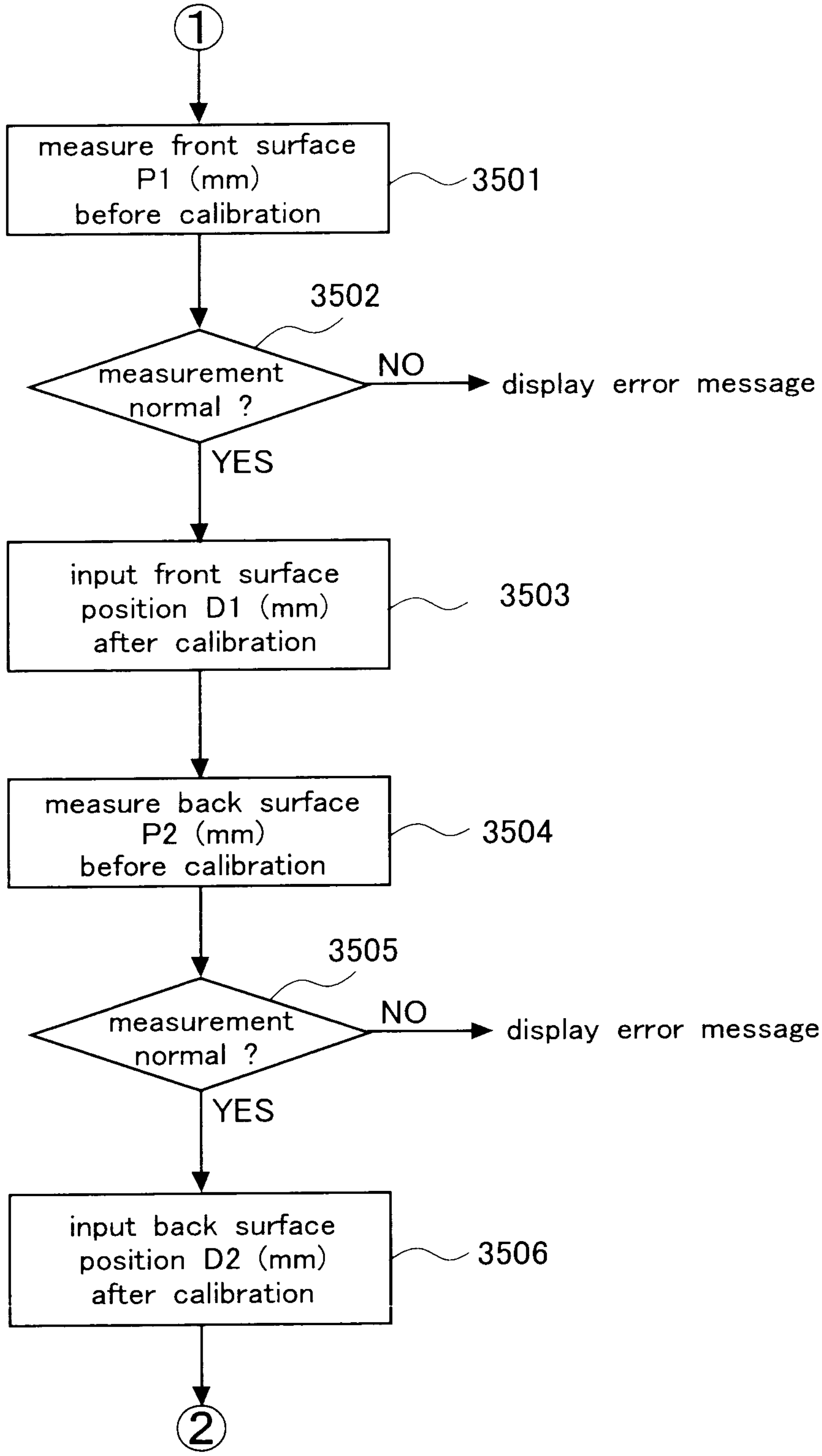
A view illustrating the process of composing a display for the image monitor (part 2)

Fig.34



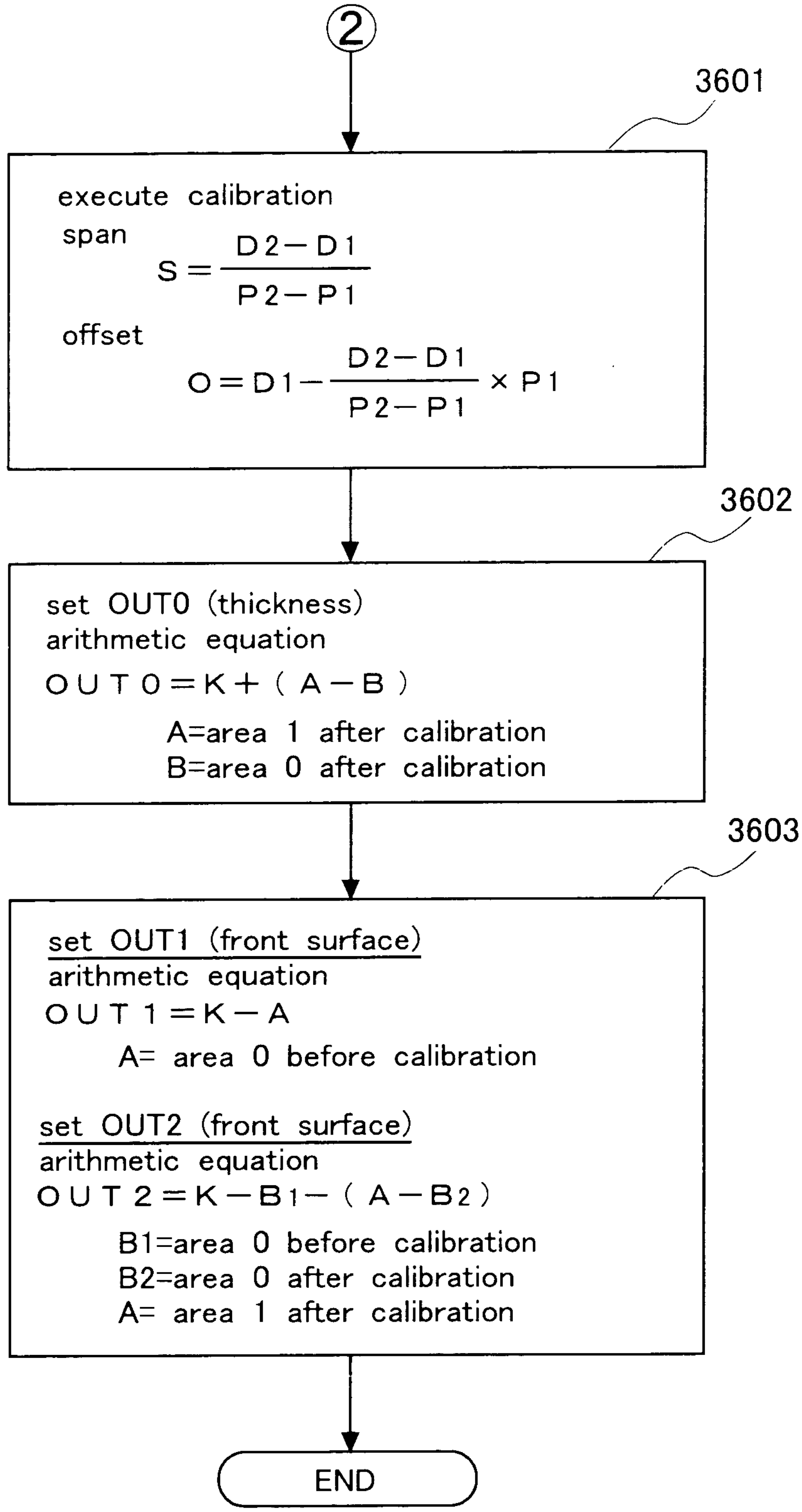
A flow chart showing the calibration process
for the computation of the thickness of a transparent member (part 1)

Fig.35



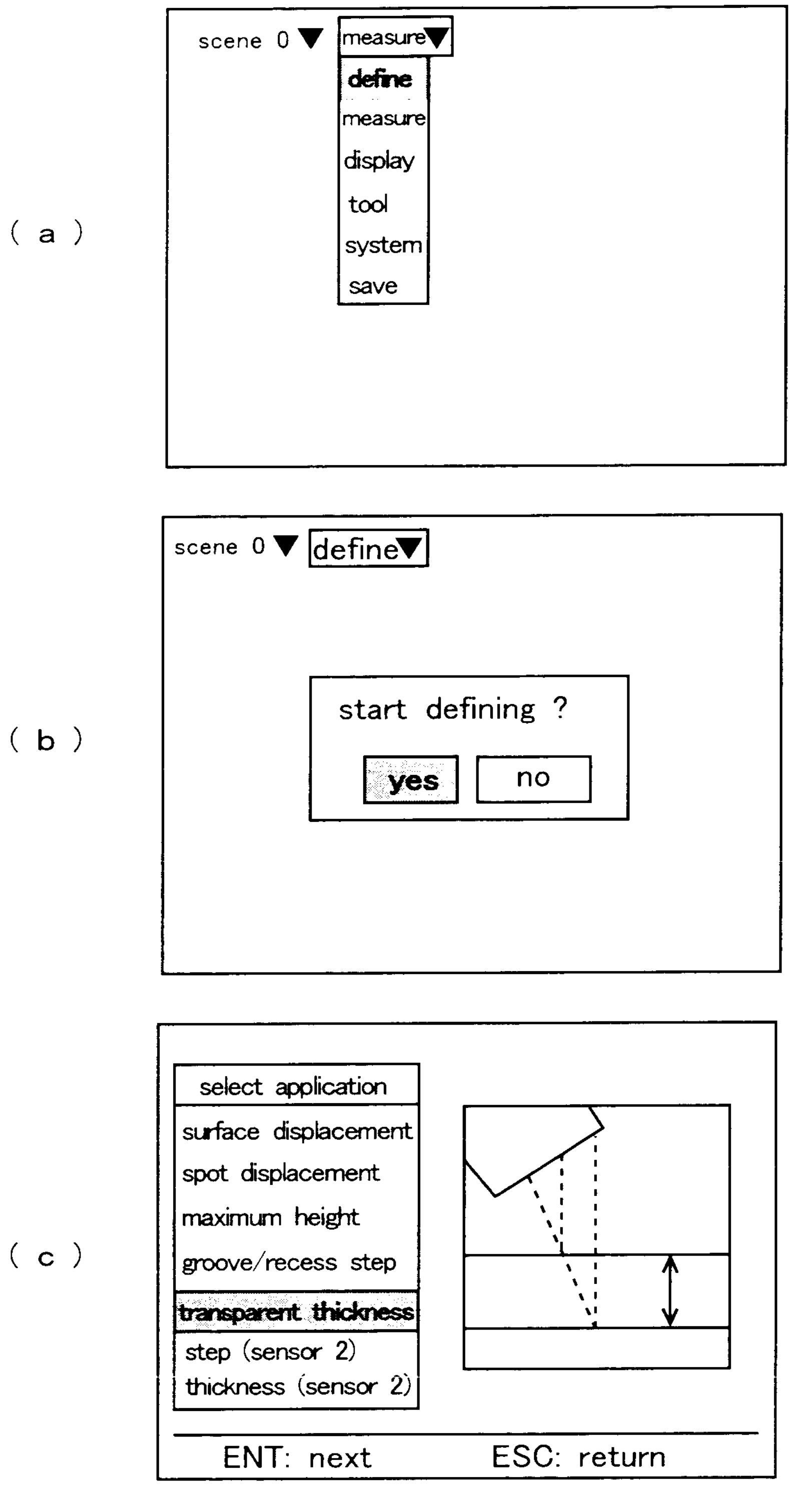
A flow chart showing the calibration process for the computation of the thickness of a transparent member (part 2)

Fig.36



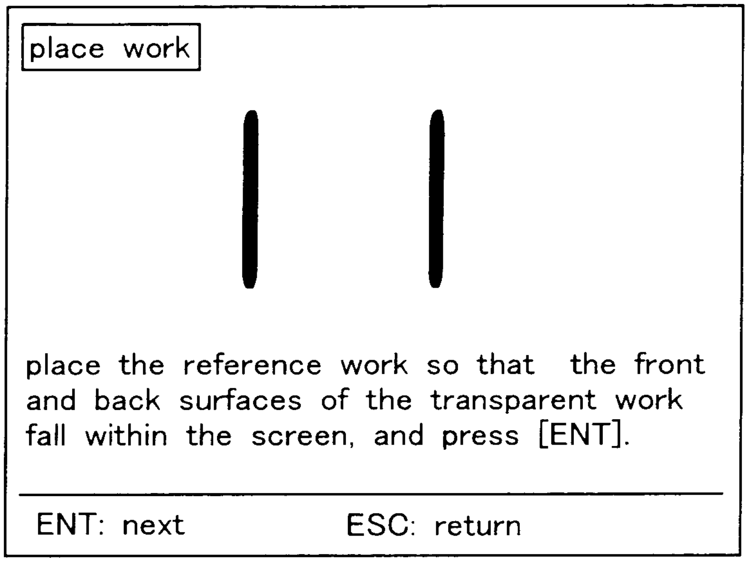
A flow chart showing the calibration process for the computation of the thickness of a transparent member (part 3)

Fig.37

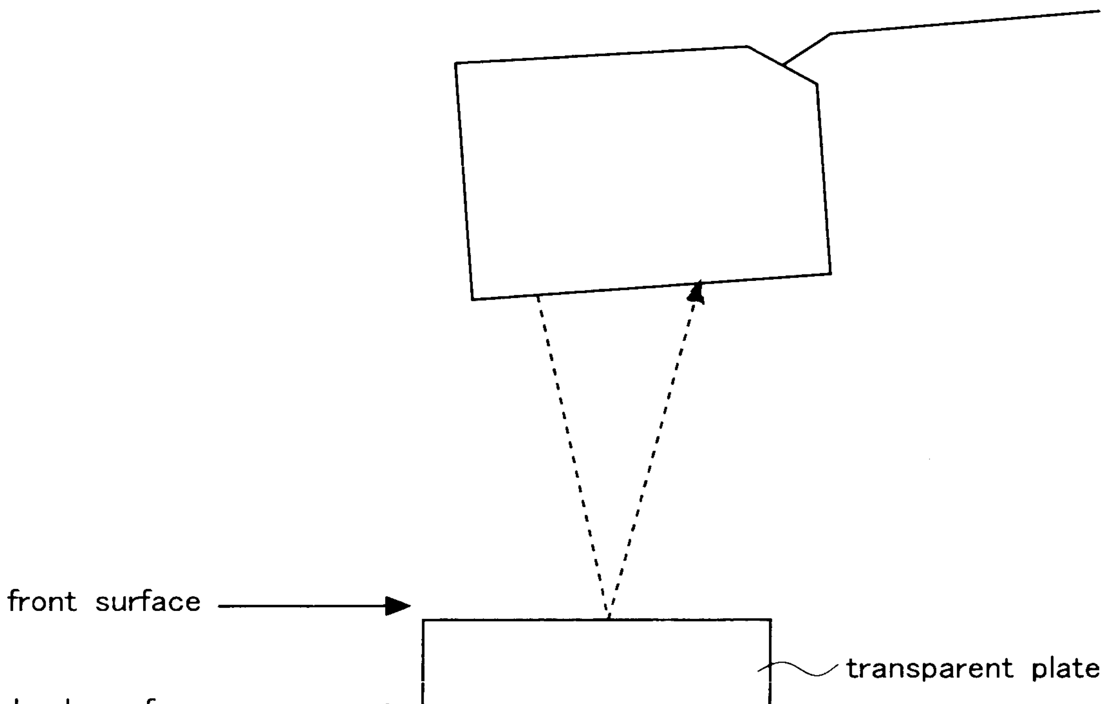


A view showing the monitor screen for the calibration operation for the computation of the thickness of a transparent member (part 1)

Fig.38



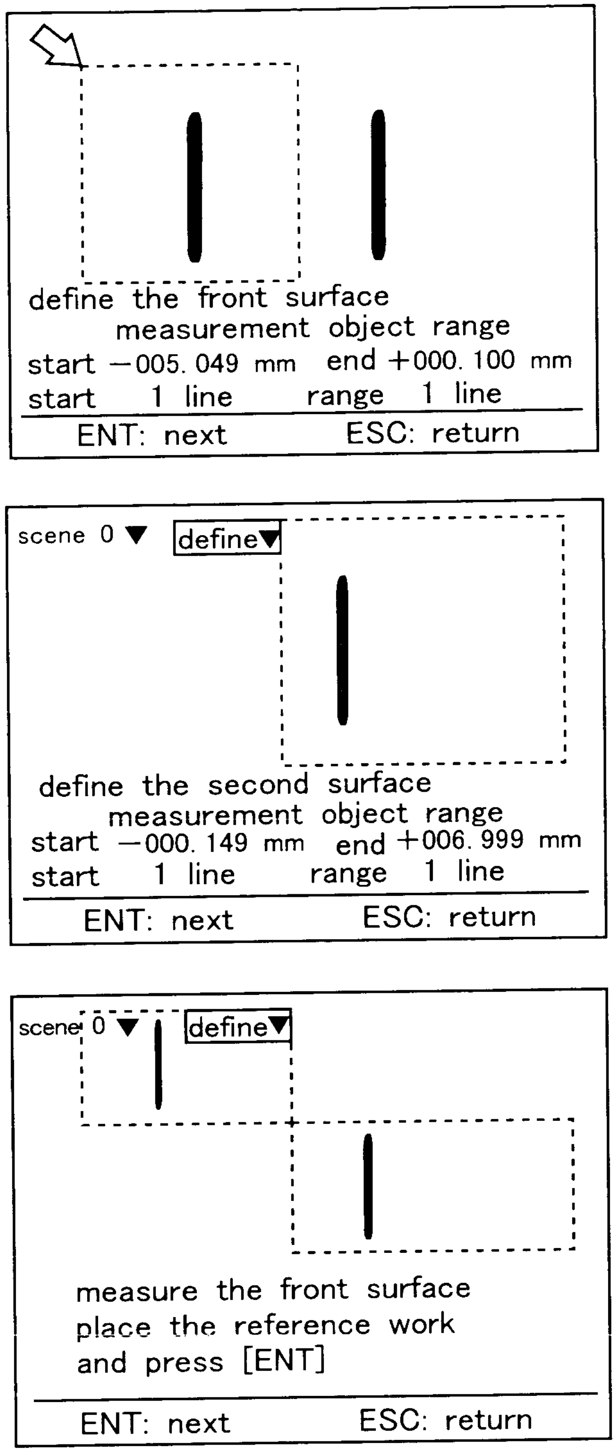
(a)



(b)

A view showing the monitor screen for the calibration operation for the computation of the thickness of a transparent member (part 2)

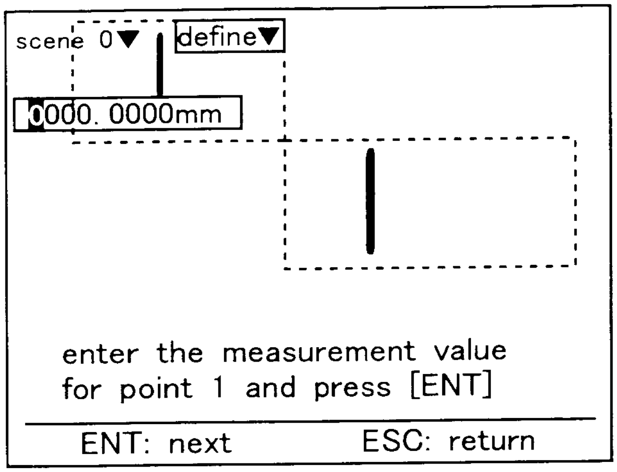
Fig.39



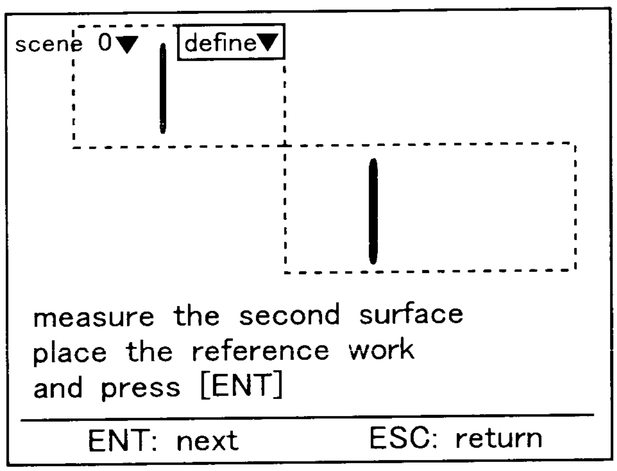
A view showing the monitor screen for the calibration operation for the computation of the thickness of a transparent member (part 3)

Fig.40

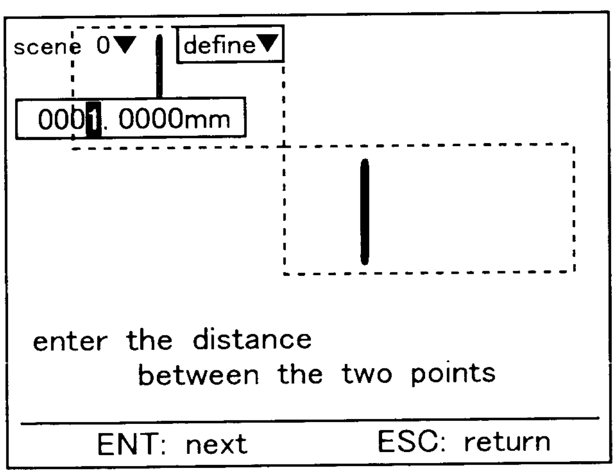
(a)



(b)



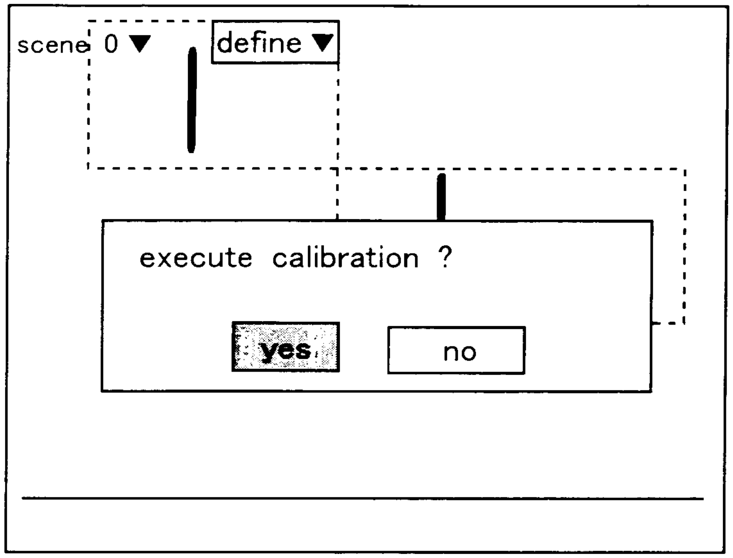
(c)



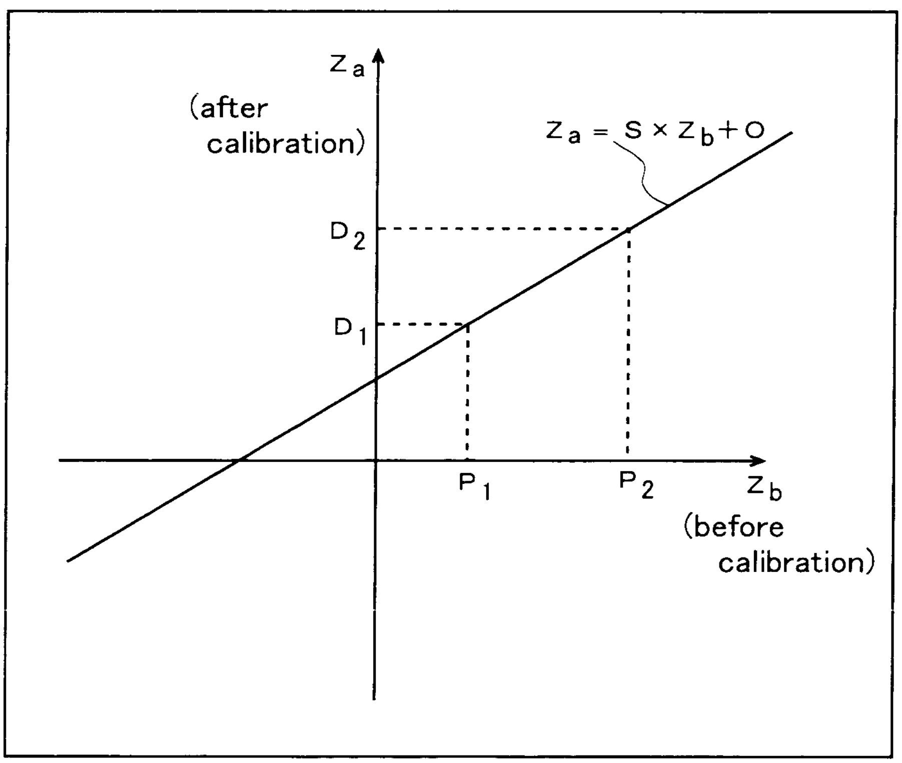
A view showing the monitor screen for the calibration operation for the computation of the thickness of a transparent member (part 4)

Fig.41

(a)

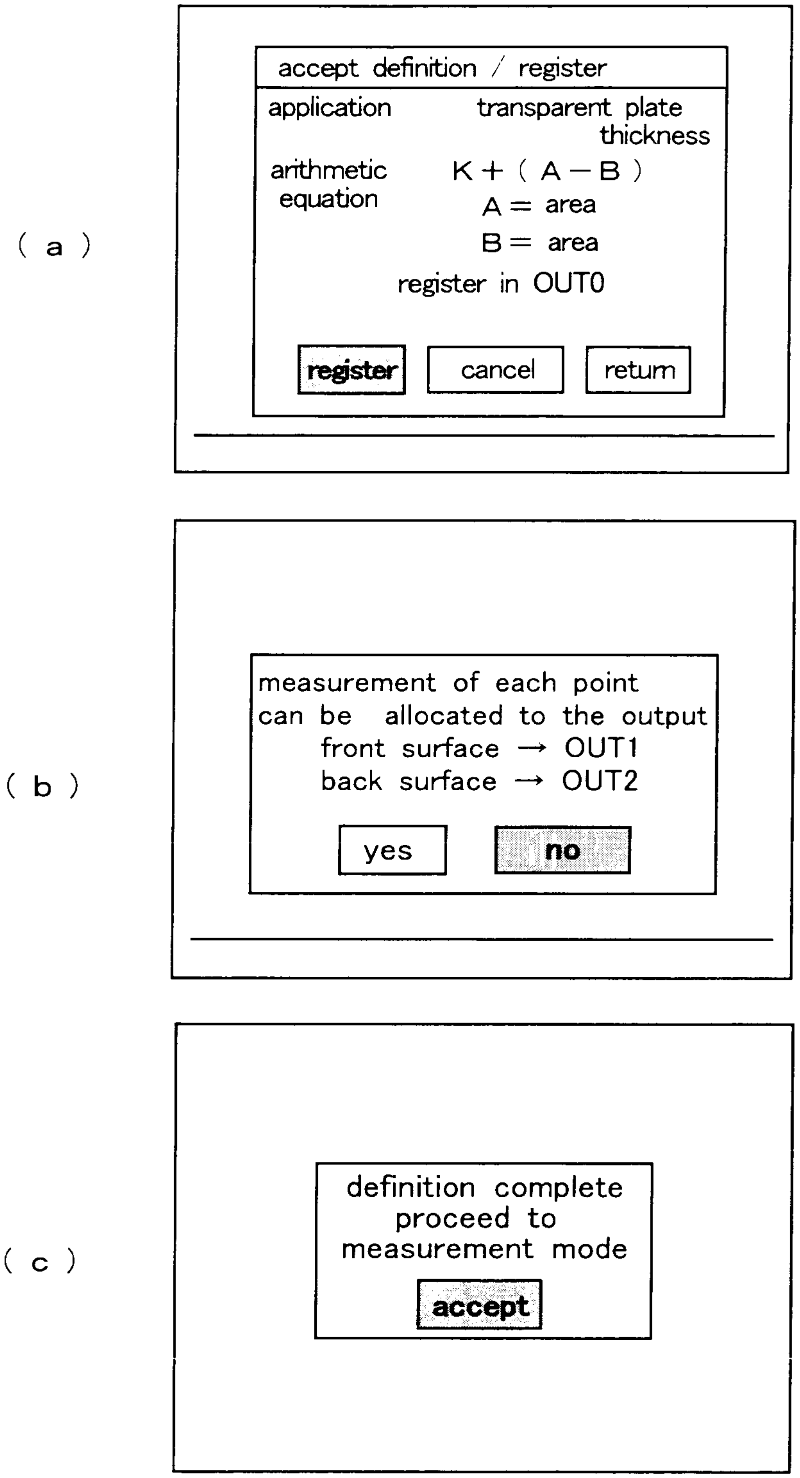


(b)



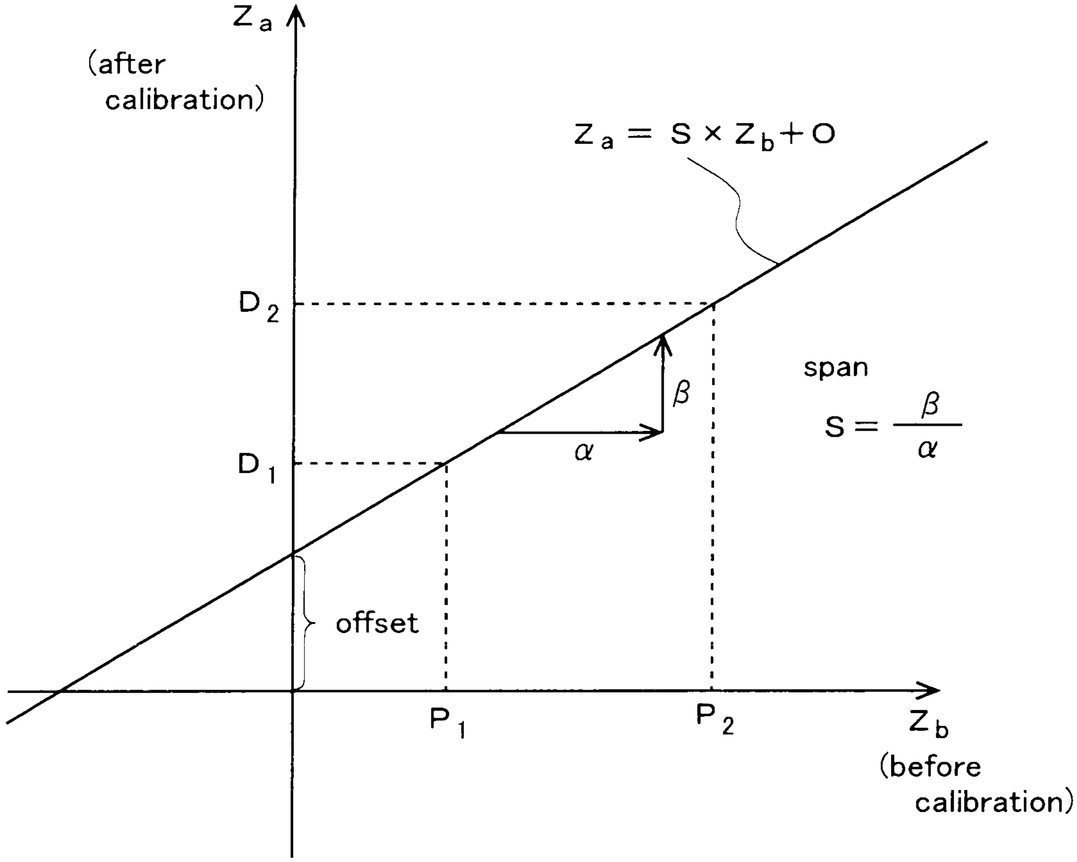
A view showing the monitor screen for the calibration operation for the computation of the thickness of a transparent member (part 5)

Fig.42



A view showing the monitor screen for the calibration operation for the computation of the thickness of a transparent member (part 6)

Fig.43



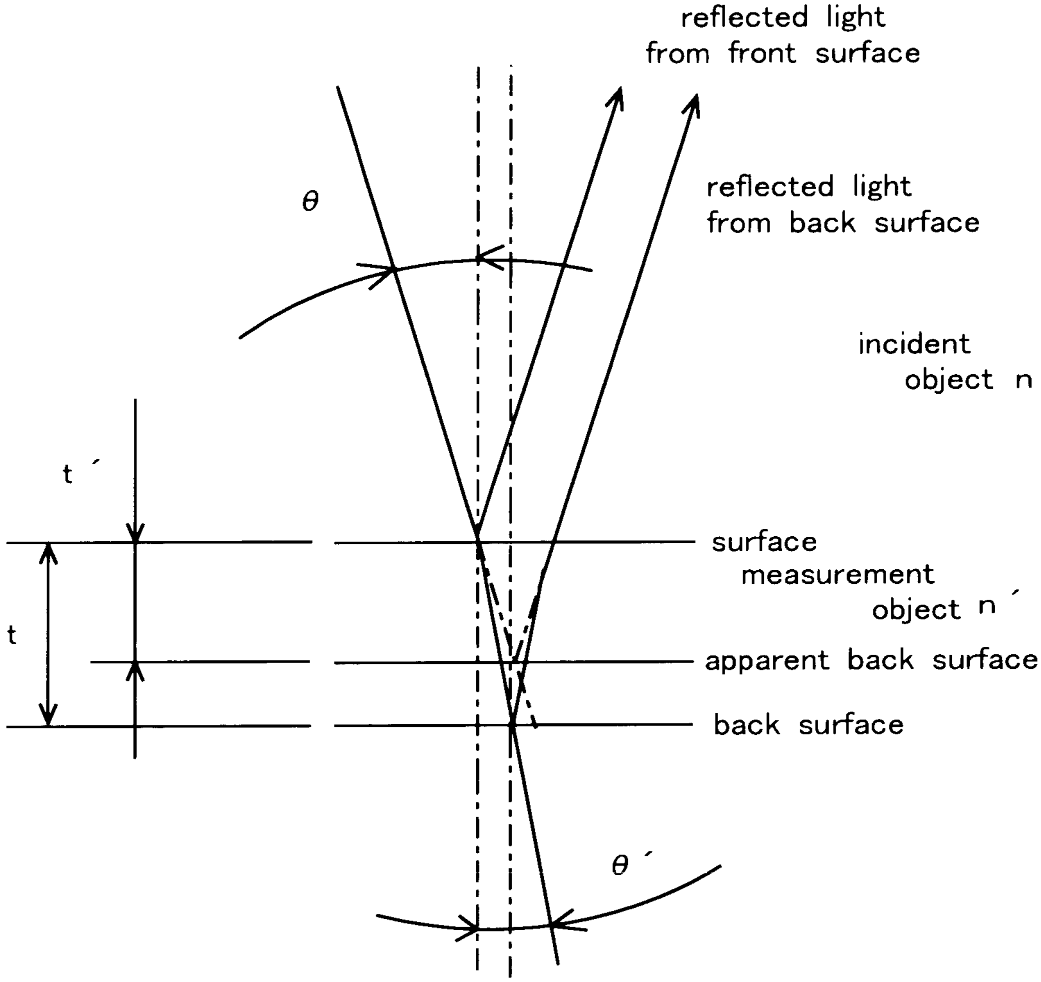
$$S = \frac{D_2 - D_1}{P_2 - P_1}$$

$$O = D_1 - \frac{D_2 - D_1}{P_2 - P_1} \times P_1$$

A view showing the algorithm for the calibration operation for the computation of the thickness of a transparent member

Title: VISUAL DISPLACEMENT
SENSOR
Inventor(s): Tatsuya Matsunaga, et al.
DOCKET NO.: 058856-0106

Fig.44



$$t = \frac{\tan\ \theta}{\tan\left(\sin^{-1}\left(\frac{n}{n'}\sin\ \theta\right)\right)}\ t'$$

t	:thickness of measurement object
t´	:sensor output value
θ	:sensor light beam incident angle
n	:refractive index of incident object (n=1 normally air)
n´	:refractive index of measurement object

refractive indices of typical transparent materials	
air : 1.002	acrylic : 1.48～1.575
glass : 1.48～1.55	polycarbonate : 1.586
water : 1.333	

A view illustrating the reason for requiring a calibration for the measurement of the thickness of a transparent member by using the visual displacement sensor